



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

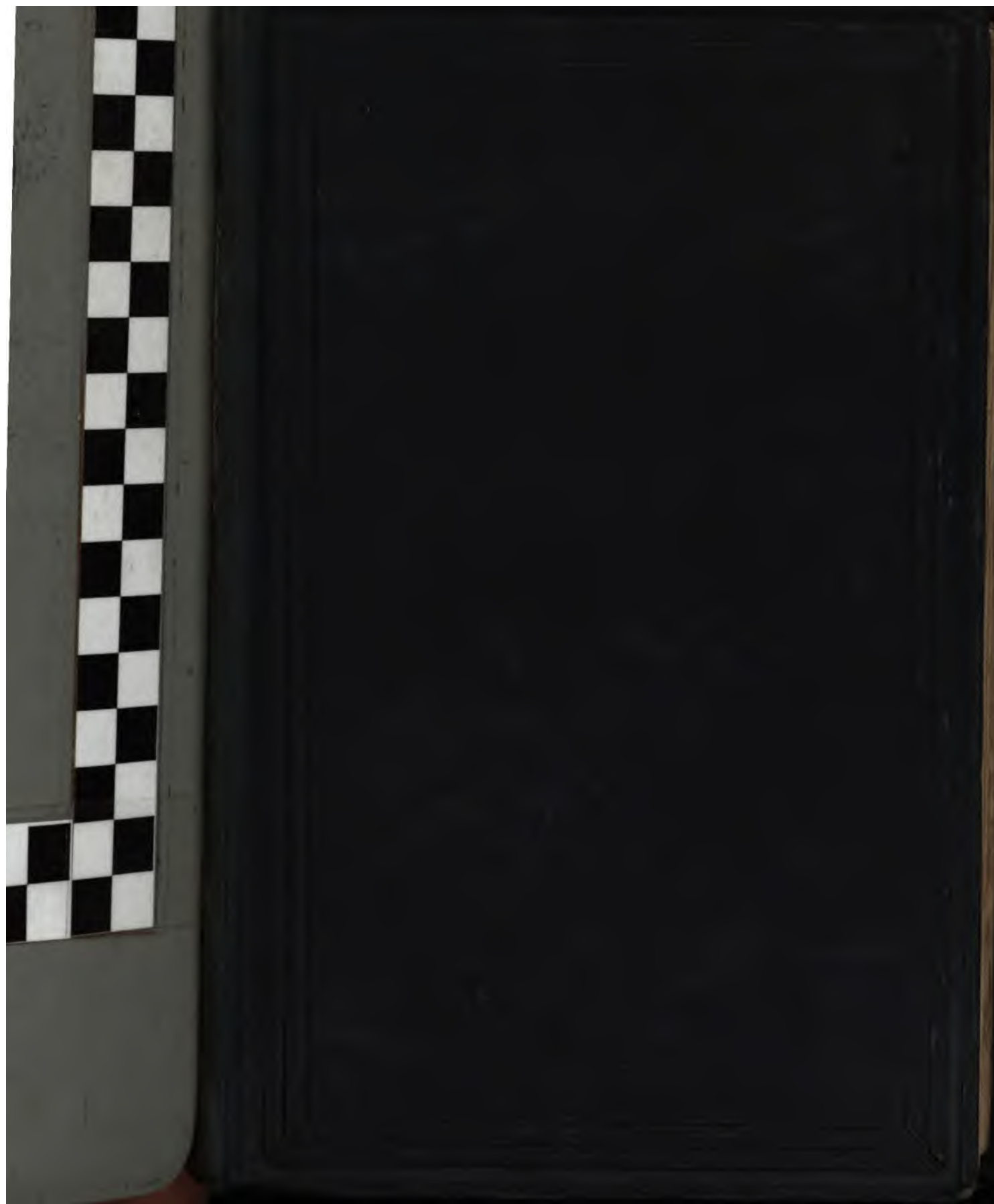
Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

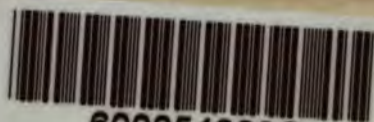
We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>





600054083Q

42.

1188.

ADAY'S

MANIPULATION.

FARADAY'S
CHEMICAL MANIPULATION.



CHEMICAL MANIPULATION:

BEING

INSTRUCTIONS

TO

STUDENTS IN CHEMISTRY

ON THE

METHODS OF PERFORMING EXPERIMENTS OF DEMONSTRATION
OR RESEARCH, WITH ACCURACY AND SUCCESS.

BY

MICHAEL FARADAY,

D.C.L. F.R.S. F.G.S. M.R.I.

THIRD EDITION, REVISED.



LONDON:

JOHN MURRAY, ALBEMARLE-STREET.

MD CCC XLII.

1188.



TO
THE PRESIDENT,
VICE-PRESIDENTS,
MANAGERS, VISITORS, AND MEMBERS
OF THE
Royal Institution of Great Britain,

THIS CONTRIBUTION TO THE SCIENCE
WHICH HAS BEEN SO EMINENTLY PURSUED IN THEIR LABORATORY AND
THEATRE,

IS RESPECTFULLY INSCRIBED,

BY THEIR FAITHFUL SERVANT,

THE AUTHOR.

PREFACE TO THE SECOND EDITION.

My reason for venturing to add a new work on Chemistry to the many excellent productions which previously existed, was because there seemed to be a deficiency in the particular kind of instruction which it was my intention to convey. In the execution of my task, I endeavoured to make every other point subordinate to the one of embodying a mass of useful information on the practice of Experimental Chemistry. Being intended especially as a book of instruction, no attempts were made to render it pleasing, otherwise than by rendering it effectual; for I concluded that, if the work taught clearly what it was intended to inculcate, the high interest always belonging to a well made or successful experiment would be abundantly sufficient to give it all the requisite charms, and more than enough to make it valuable in the eyes of those for whom it was designed.

It may well be supposed that the confirmation of my opinion by the necessity of a second Edition of the work affords me no slight pleasure, and I feel, even more than I did at first, the propriety of the view which I had taken of the character of the instruction required.

In the present edition I have made many correc-

tions and alterations, without enlarging the book ; for although I have always felt that much valuable instruction in Manipulation had been omitted, yet deeming the utility of the work to depend greatly on its limitation to a moderate size, I found it impossible to introduce any additional matter without displacing that which was more important ; nor do I anticipate that I shall incur blame by withholding that which has not been tried, and, in my own judgment, is of less moment than that which experience has proved to be useful and desirable.

M. FARADAY

ROYAL INSTITUTION,
June, 1842.

FOR several years the second edition of this work has been out of print, and I had no intention of reprinting it, because circumstances of health and occupation prevented me from introducing into a third edition those changes which the progress of time and chemical science might seem to make necessary.

During those years, however, the acceptable testimony of many to its value, in their estimation, was afforded by continual inquiry for it of Mr. Murray, and by letters to myself. I have, therefore, resolved to reprint it; and being persuaded that the considerations expressed in the preface to the second edition still hold good—that whatever I might put into the book, I could not take much out—and, that organic, mineral, and gaseous analysis, reducing, assaying, and other such important branches, should rather be treated separately and fully, than slightly hinted at in a preparatory work like the present—I have resolved to reprint it with little other change than corrections, with the hope that the work will be as acceptable to those for whom it is intended as it was on former occasions.

M. FARADAY.

TABLE OF CONTENTS.

	Page
INTRODUCTION	1
SECT. I. The Laboratory	11
II. Balance; Weighing	24
III. Measures; Measuring	66
IV. Sources and Management of Heat	83
1. Furnaces	84
2. Lamps	102
3. Blow-pipes	109
4. Thermometers	135
V. Comminution; Trituration, Mortars, Granulation	147
VI. Solution, Infusion, Digestion	167
VII. Distillation; Sublimation	197
VIII. Precipitation	230
IX. Filtration, Decantation, Washing	237
X. Crystallization	254
XI. Evaporation; Desiccation	263
XII. Coloured Tests; Neutralization	274
XIII. Crucible Operations; Fusion; Reduction	286
XIV. Furnace Tube Operations	305

SECT.	Page
XV. Pneumatic Manipulation, or Management of Gases	317
1. Pneumatic Troughs, Jars, &c.	317
2. Production, Retention, and Transference of Gases	324
3. Measurement of Gases	334
4. Of larger and independent Vessels for the Retaining and Storing of Gas	350
5. Connection and Communication	362
6. Air-pumps, Syringes, and the Operations performed with them	374
7. Correction of the Volume of Gases for Temperature and Pressure	382
8. Weighing of Gases or Air	387
XVI. Tube Chemistry	398
XVII. Electricity	432
1. Franklinic Electricity	433
2. Voltaic Electricity	453
XVIII. Lutes; Cements	477
XIX. Bending, Blowing, and Cutting of Glass	493
XX. Cleanliness and Cleansing	535
XXI. General Rules for young Experimenters	558
XXII. Uses of Equivalents—Wollaston's Scale	564
XXIII. Miscellanea	576
1. Uses of Corks	576
2. Uses of Paper	578
3. Uses of Copper Wire	581
4. Uses of Glass Plates	582
5. Uses of Leaf and Sheet Metals	582
6. Uses of Soft Windsor Brick	584
7. Conduction of Heat	585
8. Uses of Reflective and Receptive Powers	586
9. Writing on Glass	588
10. Smelling by a Tube	589
11. Screens and Masks for the Eyes and Face	589
12. Silvering Glass	591

TABLE OF CONTENTS.		xiii
Sect.		Page
XXIII. (<i>continued.</i>)		
13. Phosphorescence		592
14. Uses of Solar Radiant Matter		593
15. Magnetism		594
XXIV. A Course of Inductive and Instructive Practices		598
2. Balance ; Weighing		599
3. Measures ; Measuring		602
4. Management of Heat		603
5. Communion		605
6. Solution, Digestion, Infusion		607
7. Distillation, Sublimation		610
8. Precipitation		613
9. Filtration, Decantation, Washing		615
10. Crystallization		617
11. Evaporation ; Desiccation		618
12. Coloured Tests ; Neutralization		619
13. Crucible Operations		621
14. Furnace Tube Operations		624
15. Pneumatic Manipulation		626
16. Tube Chemistry		636
17. Electricity		640
18. Lutes ; Cements		642
19. Blowing and Cutting of Glass		643
20. Cleanliness and Cleansing		645
22. Uses of the Scale of Equivalents, &c.		645
23. Miscellanea		646
Index		649

CHEMICAL MANIPULATION.

INTRODUCTION.

CHEMISTRY is necessarily an experimental science: its conclusions are drawn from data, and its principles supported by evidence derived from facts. A constant appeal to facts, therefore, is necessary; and yet so small, comparatively, is the number of these presented naturally to us, that, were we to bound our knowledge by them, it would have but a small extent, and in that limited state be exceedingly uncertain in its nature. To supply the deficiency, new facts have been and are created by *experiment*, the contrivance and hand of the philosopher being employed in their production and variation. In reference to the varieties of inert matter, their possible forms, states, and properties, and the powers which influence them, Chemistry, if occupied only in the observation of such phenomena as are presented by Nature, would do little more than record the comparatively quiescent state of things which has followed the active exertion of the inherent powers of matter; and the chemist would have but little opportunity of observing substances in their energetic state, or of witnessing the phenomena which these powers are able to produce. Even when such appearances might naturally be presented, either their vastness, their complication, or their rarity, would in most cases prevent the deduction of correct conclusions.

If it were our object to learn as much as possible of the nature of a substance taken at random from the surface of the earth, how slight would be the amount of information derived from a consideration of it in its natural state! We

should be able to decide, perhaps, that the air did not affect it; that light did not sensibly injure it; that the rain or dews did not dissolve it; that the difference between summer and winter did not apparently alter it; that the ground beneath was not affected by it; and perhaps some other points respecting its nature might be ascertained: but what are these compared to the knowledge gained by submitting it to a high temperature, either alone or in contact with different substances; by subjecting it to the action of other bodies as solvents under peculiar circumstances, and operating upon it in the numberless ways which art and experience dictate to us? Unaltered as it appeared before, it may now change its form, yield new substances and enter into new combinations, and, instead of being an inert lump, may prove an active and powerful agent in many of the purposes of civilized life. Hence the importance of multiplying facts by every possible means, whilst engaged in such pursuits; and hence Chemistry is necessarily an experimental science.

Great, therefore, are the advantages which result from experiment; and especially is this the case in Chemistry, for it may safely be stated that more than nine-tenths of the facts upon which the science is founded are evolved by artificial means. Without, indeed, the great body of truth thus furnished, the science could not have existed; and from this dependence on experiment it derives many of its peculiar charms.

Such considerations are abundantly sufficient to show the intrinsic importance of experiments; and when to them are added those which arise from the great extent and dominion of the science itself over the powers and properties of all matter, and its influence in administering to the wants, comforts, and pleasures of life, little need be urged in extenuation of an attempt to facilitate, to students in Chemistry, the acquirement of the art of making those experiments which are so essential to its progress.

Experiment has two principal objects—the proof or demonstration, and the extension, of our present knowledge. When an experiment has been devised, its general nature and principles arranged in the mind, and the causes to be

brought into action, with the effect to be expected, properly considered, then it has to be performed. The consideration of the ultimate objects of an experiment, and also the particular contrivance or mode by which the results are to be produced, being mental in their nature, there remains the mere performance of it, which may properly enough be expressed by the term *manipulation*.

Notwithstanding this subordinate character of manipulation, it is yet of high importance in an experimental science, and particularly in Chemistry. The person who could devise only, without knowing how to perform, would not be able to extend his knowledge far, or make it useful; and where the doubts or questions that arise in the mind are best answered by the result of an experiment, whatever enables the philosopher to perform the experiment in the simplest, quickest, and most correct manner, cannot but be esteemed by him as of the utmost value. It is, indeed, to him like the external senses to the mind—a channel of information by which things before unperceived are made known, and like them it has its continual use.

There are many experiments, and even whole trains of research, which are essentially dependent for success on mere manipulation: such, for instance, are various analytical processes, in which the principles of the process and the modes of detecting and separating the substances being well known, the accuracy with which they are successively separated, and their quantities correctly ascertained, depends entirely upon manipulation. Such is the case in most of the analyses of ordinary siliceous, calcareous, or aluminous stones: such is also the case in the analysis of organic substances by any of the processes recommended in chemical works: it is the same with the manufacture of many chemical preparations; and the separation of four or five gases, a problem of frequent occurrence, is to the chemist who has made only moderate progress in his studies, a matter entirely of manipulation.

By accurate and ready manipulation, therefore, an advantage is gained independent of that belonging to the knowledge of the principles of the science, and this is so con-

siderable, that of two persons having otherwise equal talents and information, the one who manipulates best will very soon be in advance of the other; for the one may obtain satisfactory conclusions from his experimental inquiries, while the other is left in doubt or led astray by his imperfect and incorrect results. This advantage may be illustrated by the use of the tinder syringe, a small instrument consisting of a cylinder about half an inch in diameter, and three or four inches in length, closed at one end and fitted with a piston, to the extremity of which a piece of amadou is fastened: by forcing the piston down and compressing the air *suddenly*, so much heat is evolved as to fire the tinder. Some persons cannot perform this simple experiment, whatever may be the strength or dexterity which they endeavour to bring into action; whilst others, with a very slight force, will in every instance obtain the effect desired, and produce the required ignition. Were this a new experiment to the persons making it, the object being to prove whether air when highly compressed gives out much heat or not,—the first person would either come to a wrong conclusion, or, if he doubted the success of his experiment, would arrive at none at all, whilst the second would be enabled to form a correct and affirmative decision, and thus would have added an important fact to his previous knowledge.

In other cases where the appearances may be such that we have no method of anticipating, or, when produced, of correcting them, as in the habitudes of an unknown substance or its action upon other bodies, then careful manipulation is of the utmost importance: without it the appearances produced may arise or be modified by extraneous substances present, or by other causes overlooked; and the conclusions may be erroneous at the time when it is most important they should be correct, because the subject is new, and because from its novelty but a small proportion of previous knowledge will bear upon the point and help to correct the error. Nor is the tyro alone thus liable to be misguided; for it would not be difficult to point out instances where the most acute minds have in this way been led to false conclusions.

Another consequence of skilful manipulation is, that by its means a train of research may frequently be carried much farther than its original object ; and that in two ways. In the first place, the occurrence of clear and distinct phenomena, besides illustrating satisfactorily the direct object of inquiry, frequently suggests to the mind collateral views, which, pursued and extended, terminate in additional chains of information and discovery ; whereas, if the experiments be less clear, though sufficient may be distinguished to satisfy the mind on the subject in question, nothing more is done, and the progress of knowledge is stopped. In the second place the operations may be performed on comparatively very minute quantities ; and that which in the hands of one person had hardly sufficed to supply very general information of its nature, may in those of another be made to yield matter for a full and minute investigation, terminating in the development of its nature and habits, with a perfection equal to that obtained with the largest masses. Frequent illustrations of the importance of manipulation in thus effecting all that can be desired with small quantities, is afforded in the occasions that arise in testing for arsenic ; for the fractions of a single grain will in the hands of some persons afford the most striking and convincing proofs, whilst many grains will with others present no satisfactory conclusion.

When the substance under examination is rare (and that is frequently the case both in natural and artificial productions), the facility of working with small quantities is of the highest importance, as otherwise the opportunity of gaining information may be entirely lost, or if preserved is retained only at a great expense. There existed in the British Museum a small fragment of a black stone, the source and history of which were unknown : it was unique, no other specimen being in the Museum or known to be in existence ; yet as it presented some peculiar characters, Mr. Hatchett was induced to examine it, and, working with a portion of the stone weighing not more than 200 grains, he was enabled to discover in it a new metal, which he distinguished by its various characters from all those previously

known, and which he named Columbium. Ekeberg afterwards discovered a metal which he named Tantalum, conceiving it to have been observed and distinguished for the first time by himself; but Dr. Wollaston, who examined it and compared it with Columbium, was able to identify it with that metal, although he had not more than five grains of the stone from the British Museum upon which to make his experiments.

Finally, habits of correct and delicate manipulation very much facilitate experimental inquiries at all times. It is not in difficult researches only that it is desirable, but even in such common operations as testing for lime, or iron, or sulphuric acid, its advantages become manifest: for either time is shortened, or the apparatus considered as necessary is diminished, or effectual substitution is made for those that may be wanting; and thus the experiment becomes easy, where otherwise it would be considered impossible. Besides facilitating such inquiries, it also diminishes the expense both in materials and apparatus, and it produces beneficial habits in the mind by exercising it both in invention and perception, even in this subordinate part of its operations. "Nothing," as Dr. Johnson observes, "is to be considered as a trifle by which the mind is inured to caution, foresight, and circumspection. The same skill, and often the same degree of skill, is exerted in great and little things."

The importance of instruction in manipulation was long felt by the author during his experience in the Royal Institution of Great Britain; and the deficiency in the means of teaching it induced him to think he might perform an acceptable service by putting together such information on the subject as there was reason to suppose would be generally useful to the student. No book contains those minute directions which are necessary in the present extensively cultivated state of the science; nor can verbal instructions teach that perfection of manipulation which is only to be gained by constant operation. But there is so much that can be taught, so much that can be suggested by such instruction, that it seems extraordinary not one of the many treatises upon Chemistry has been devoted to this subject, especially

when it is considered that of the great numbers who now desire, or are assumed, to have some knowledge of Chemistry, very few have access to competent practical sources.

Such are the considerations which have given rise to the present work, and under their influence it has been composed. The object of the volume is to facilitate to the young chemist the acquirement of manipulation, and, by consequence, his progress in the science itself. It does not attempt to inculcate the *principles* of the science, but the *practice*; neither does it claim to teach a *habit of reasoning*, but has solely in view the *art of experimenting*; and though sometimes it may be necessary to speak of the properties of bodies, or to draw conclusions, it will always be done in subordination to the main object. The volume, indeed, is not intended to supply the place, or imitate in its nature any one of the numerous and useful works on Chemistry now extant, but to be rather an accompaniment to all of them, supplying that portion of knowledge which, however essential to the pupil, was not of a nature to consort with their more scientific contents.

In the pursuit of this object it is intended to describe—

The conveniences and requisites of a Laboratory.

General Chemical Apparatus, and its uses.

The methods of performing Chemical Operations.

The facilities acquired by Practice; and

The causes which make Experiments fail or succeed.

Although a laboratory will be described in a complete state, well appointed, and with most of the conveniences that the author is acquainted with, yet it is intended that the directions shall be such as to enable the experimenter to perform the operations, when desirable, with the smallest number of requisites; for though many may wish to be made acquainted with all that is useful, yet to a much larger number of persons a knowledge of the few essentials is of the greatest consequence. To omit the description of a laboratory, in a work devoted to chemical experiment, would of course be improper; but it would certainly be a

much greater error to omit showing, as far as the author's knowledge will serve him, how many things may be dispensed with in cases of necessity, and how few are the absolute requisites for the greater number of operations. The general principles upon which apparatus is formed will be inculcated, for the purpose of leading the student to the *ready substitution* of one thing for another, and to that *contrivance* by which the wants of the operator may be obviated; and therefore *small, temporary, and generally useful* apparatus will be pointed out as often as possible.

It is not intended to describe processes particularly, such as the preparation of each of the acids, or of the alkalies, or of other important substances; or such as are numerous in the chemical arts, though reference to them will probably be frequent. The work is intended principally to assist in obtaining a knowledge of the chemistry of research, and not the chemistry of the arts, or rather not of the ultimate and refined processes of chemical preparations; otherwise than as, the principles being the same, the instruction which is advantageous in the one case will be useful in the other. The book is principally for beginners; but this will not induce the author to reject as improper any information he may have to give relative to the facilities of making experiments, though they may relate to the production of refined and abstruse results. Lastly, it may be remarked, that it is intended for a country where most of the requisites are supplied in trade.

Professedly disclaiming a scientific character, the arrangement of the volume is one of mere convenience, but it has not been adopted without considerable thought. As the work was not intended to teach the principles of Chemistry, but to be a useful laboratory companion, that arrangement was considered as best, which, though not scientific, seems most convenient for including the different parts of manipulation, without any great violence to the relation of the whole subject. It has therefore been divided into *sections*, or principal divisions: but the professed object of each has not always been strictly adhered to, since it has often been found convenient and useful to include information on other

points, which nevertheless have always some degree of connexion with the subject under consideration. Those who may read the work for instruction will probably not find many difficulties in the arrangement, particularly as they will be aided by a copious index.

Such are the objects of the present book, and the means by which their attainment has been attempted. That it is faulty the author has no doubt; indeed, he is thoroughly convinced it cannot be otherwise. It contains little more than a selection from the experimental practices and methods of one person; and though in the more ordinary operations of Chemistry the author's may resemble those of most other chemists, and therefore be well suited for general adoption, yet in those peculiar facilities that others may by practice have attained, it must necessarily be imperfect. Acquisitions of this kind made by any chemist must be in relation to his particular trains of research; and as there are but few who possess the power of ranging through the whole of this extensive science, it cannot be expected that many should have perfect knowledge of the facilities belonging to all departments of experimental chemistry.

Finally, he has to observe, with reference to the pupil's expectations in consulting this book, that even supposing it were perfect, it could only point out the methods for him to *practise*; and therefore, though aided by the principles of the science detailed in other works, and the experimental directions in the present volume, he must still perfect his knowledge by study and the labour of his own hands.

SECTION I.

THE LABORATORY.

1. As the Laboratory is a spot where every chemist will pass a great portion of his time, it is natural that its arrangement and furniture should at first claim much of his attention ; for, being the place peculiarly fitted up for the performance of chemical experiments, fitness for that purpose must have material influence over the facilities required for those practical exercises, which by their results are so important in the formation and correction of his opinions.

It is, however, very curious, and at the same time instructive, to remark the different views taken by chemists as to the essentials and requisites of a laboratory. Some will not think it approaches to perfection unless it consists of a large room on the ground floor, well stocked with tables, cupboards, furnaces, and various other *et cæteras* ; and having in connexion with it a second room, dry, comfortable and fit for the reception of the balance, air-pump, and similar apparatus ; and a third apartment, which, however, may be a kitchen or even a cellar, intended to contain moveable furnaces, bricks, tiles, sand, and the numerous rough materials which are now and then required : whilst others will be satisfied with a small cupboard, and think *that* sufficient to contain all that is required for their operations. Much of this variety of opinion depends upon the difference in the pursuits of the persons. He who studies chemistry by microscopical experiments, testing the qualities rather than ascertaining the quantities of matter, may find a cupboard abundantly sufficient for his operations, or may even pack all his requisites on a tray ; whilst the person who is engaged in metallurgical processes, in extensive experiments on gaseous matter, or in the applications of

chemistry to the arts, will find a laboratory essential to his progress. Part of the difference in opinion is founded, however, on mere matter of taste and inclination; and those who love the science, and are in circumstances to pursue it liberally, will probably never think a damp kitchen or a small attic sufficient for their purpose. It was in a spirit of this kind that the late Dr. Marcet, when he purchased a house on the banks of the lake of Geneva, which unfortunately he did not live long to occupy, appropriated one of the best rooms in it to the purposes of a laboratory, not knowing, as he himself said, why he should not do what he could to make that a pleasant place where he found so much pleasure.

2. When the laboratory is attached to a public institution, where it is devoted to the progress and teaching of the science, and where it is intended to facilitate the researches of two or three persons at the same time, it must necessarily be of large size, possessing the accompaniments of an apparatus and a store-room, and all the facilities which have been found useful in variety of research, and in extensive operations.

3. Hence it may be observed, that, in various circumstances, the place may be either large, of a moderate size, or small, and yet not in the first case exceed, or in the last fall short of what is required. In a volume like the present it will be proper that a good and convenient laboratory should be described, with all its requisites and accompaniments, the whole being adapted according to the convenience of the person who may for the first time be forming his chemical establishment.

4. If equally convenient, it is generally better that the room to be converted into or built for a laboratory should be on the ground or basement floor, as water is then easily laid on, the foul water from the sink can be readily conveyed away, and coal, carboys, and other dusty and heavy articles more conveniently carried into it. The size, as has been before intimated, may vary very much; but a room of from 20 to 24 feet by 16 or 18 feet will well answer the purpose. Where, however, it is otherwise unimportant, the

size of a laboratory intended to be actively used should be as large as possible; otherwise, when chemical apparatus accumulates, and several sets of experiments are in progress at once, it may be found that confusion and error arise solely from the want of room.

5. If the place is to be built for the purpose, then no difficulty will arise in the construction and arrangement of the flues and lights; which, though of great importance, cannot usually be introduced or altered easily in a room already finished. Where the opportunity occurs, the place should be furnished with several flues, and an advantage is gained if their terminations in the room are separated a little distance from each other. Sometimes it is easy to spread these over one side or wall of the room, the stack in which they unite being carried up immediately in their neighbourhood. One flue is essentially necessary for the draught of that furnace which will be lighted daily for ordinary operations, and the ventilation and warming of the place. Another is in many cases essentially requisite for the construction of a wind furnace: another or two are desirable to serve as vents for the conveyance of fumes, or occasionally to be connected with moveable furnaces. The lower extremity of each is generally best terminated by a stone in the wall having a round aperture: when out of use, this is to be closed by a stopper; when in service, the stopper is to be withdrawn, and the flue continued by a piece of funnel-pipe fitted loosely into the hole; the pipe being continued to the furnace in operation, or otherwise terminated, according to the use to which the flue is to be put. All of them should have dampers, that perfect government of the draught may be obtained. If but one flue can be had, it must be turned to account in the best way possible, either by making it divide and terminate below in two or three places, using brickwork or funnel-pipe for this purpose, as may be convenient; or by supplying the place of furnaces and apparatus requiring flues, by such substitutes as will allow of their being dispensed with, in the manner hereafter to be described. When necessary, a brick flue may be altogether omitted, and its place supplied by

funnel-pipe, but this arrangement is almost always uncomfortable and inconvenient.

6. It is generally a matter of indifference, or at least of taste, whether a laboratory have skylights or windows, but it is always an advantage to have it well lighted. Skylights throw the light very agreeably over sand-baths and furnaces, and are exceedingly convenient in crucible operations, in consequence of the manner in which the light falls into the vessels. One side-light should, however, in all cases be provided, for the purpose of observing most advantageously the action of re-agents. Where, upon the addition of test solutions, only faint opalescence or colour is produced, considerable management is at times required for its observation in the most advantageous way; and in these cases, and generally indeed in testing, a side or window-light is by far the best. There is another point relative to the admission of light to a laboratory, which in the present state of chemical science is worthy of consideration. The solar rays have been found highly influential in causing chemical change: they effect combinations and decompositions in a manner unattainable by any other agent, and are now frequently resorted to, not merely in the preparation of peculiar substances, as chloro-carbonic acid, chloride of carbon, &c., but also in the processes of analysis where chlorine is an agent used, in new experimental researches, and in many other photochemic and, also, photographic processes. It would be well, therefore, in the construction of a laboratory, to provide, if possible, for the direct admission of solar light; and this is the more desirable, inasmuch as, were it always attainable, chemists would more frequently try the chemical powers of this peculiar agent, even now but little known, and would probably add rapidly to the comparatively small stock of knowledge we possess concerning it.

7. The mode of lighting a laboratory is to a considerable extent connected with its ventilation, and the necessity of rapidly changing the air of the place, when required, should be kept in view; for though much may be effected by means of hoods and flues, yet it is impossible at all times to prevent the contamination of the atmosphere by the

general diffusion of deleterious vapours or gases through it to such an extent as to render an immediate change of the whole very necessary.

8. There are several large articles of great utility in a laboratory, which may be almost considered as fixtures, and which require consideration, in the first place, on account of the comparative permanency of their arrangement. Of this kind are the general furnace, the tables, the sink, the cupboard, the shelves, &c. The first of these, or a *general working furnace*, is in my opinion very important, from the extreme facility which, when conveniently constructed or arranged, it gives to every ordinary operation. Its use is partly domestic, partly chemical; for it has to warm and air the place, occasionally to heat water, as well as to supply the means of raising a crucible to ignition, or of affording a high temperature to flasks through the agency of a sand-bath. These objects are best obtained by those furnaces which are built with a table top (169). The fire-place itself is constructed of brickwork with iron front and fittings, and the flue being conveyed horizontally for three or four feet, is afterwards carried off to and connected with the main flue existing in the wall. The fire-place and horizontal flue are covered with a large plate of cast-iron, of from two to three feet in width: this is formed in the middle, over the heated part, into sand-baths, a round moveable one over the fire itself, and a long fixed one over the flue. The sand-baths supply every gradation of heat, from dull redness if required, down to a temperature of 100° or lower; whilst on each side of them exists a level surface, which answers every purpose of an ordinary table, and supplies extraordinary facilities to experiments going on in the sand-bath or furnace. Nor are these advantages gained by any serious sacrifice of heating power in the furnace itself, for it is easy so to construct it as to make its ordinary combustion not more rapid than that of a common fire, and yet by closing the fire-door and opening the ash-pit to obtain a heat that will readily melt gold, silver, or cast-iron.

9. A furnace like this is best placed in the middle or towards one end of the laboratory, independent of the wall,

for then it most effectually warms the air of the place, and there is working room all round it; the flue may either descend and be carried off for a short distance underground, or it may be connected by funnel-pipe with the upright chimney (5). But if more convenient, either as occupying less of the room of a small laboratory or for other reasons, it may be placed with advantage against one side; and where the laboratory is made out of a room previously built, the best situation is generally against the fire-place, and the flue of the furnace is then easily connected with the chimney previously existing.

10. When a furnace of this kind stands against the wall, it is frequently advantageous to construct a wooden or copper hood over the sand-bath, to receive and conduct away the fumes evolved during the digestions and solutions made upon it. An extensive hood, however, requires a separate flue, or it will injure the draught of the fire; and if the furnace be in the middle of the laboratory, a fixed hood of any kind interferes with its convenient use. It is generally better in these cases to adopt the temporary hood and contrivances which will be described hereafter (392). A particular description of the construction of the furnace itself will also be given under the head of furnaces (169).

11. The *tables* are most important parts of laboratory furniture: they should be as extensive as the room will admit of, and be so placed as to allow of ready access; hence one or two of large size placed towards the middle of the room, and in such a situation as to be well lighted, are very useful. They should be made strong, and be furnished with drawers, unless indeed one be closed in by doors, so as to form cupboards having shelves within to hold rough articles; and if such a one could have a situation given it near the sink, as a kind of cleansing and washing table, its advantage would soon be experienced. The table appropriated to testing operations and experiments with corrosive fluids, as acids and alkalies, is sometimes covered with lead, or even with earthenware, glazed tiles being very convenient for the latter purpose, but a hard or heavy substance endangers the safety of thin glass vessels when laid down on it.

12. There are some things which necessarily have their appropriate and constant place on the tables. The *filtering stands* (527) are of this kind, and are thus raised to a convenient height for operations: they should have a situation chosen for them, which, though convenient for use and close to that part of the table to be kept clear for general purposes, should not be in the way of the operations constantly going on there. A drawer or other dry place in the immediate neighbourhood of these stands should be appropriated to filtering paper. The mercurial trough (734) is another apparatus which should have its assigned place upon the tables; and the particular table upon which it stands, or upon which mercurial operations are generally performed (144), should have a groove cut round it near to the edge, with a hole in one place for the facility of collecting the scattered mercury. Any of the metal which may be spilled is swept or wiped into the groove, and thence into the hole, and thus collected and preserved.

13. A *sink*, with an abundant supply of water, is very important; and although it is just possible that a jug, with a large leaden funnel and a pan beneath, may suffice, yet so advantageous is the unlimited use of water and a regular sink with its drain, that much should be done to secure them. The water should be laid on from a cistern that contains a never-failing supply, and the sink should be made of strong wood-work lined with lead; for though that metal is liable to the action of mercury and some metallic solutions, yet on the whole it is less subject to chemical action than any other substance ordinarily placed in a similar situation. The sink should be made as large as convenient, not exceeding 30 inches by 42, and should have a drain which will freely carry off all the slops and water that are likely to be thrown down. An iron stink-trap should be placed at the commencement of the drain, not merely for the purpose of preventing unpleasant smells, but for the retention of the mercury gradually washed down, which in an active laboratory of research amounts to no small quantity in two or three years. A sink is useful not only for washing bottles, glasses, jars, &c., but for many chemical

operations, such as filling airholders, washing minerals, preparing gluten, distillation, &c., and should be made convenient for all these purposes. It will of course be placed in a corner, and as much out of the way as is consistent with its free use; a place in the immediate neighbourhood being appropriated to its cleansing accompaniments, pails, pans, brushes, brooms, &c.

14. *Cupboards* are so useful, that one, or, if possible, more, with shelves inside, ought to be provided. In these are to be kept clean test-glasses, jars, measures, retorts, flasks, receivers, &c., for here they are preserved from the dust and dirt which are constantly moving and settling in the laboratory itself. The shelves should be placed at different intervals, so as to receive glasses of various sizes; and one or two of them should have a number of round holes cut out, from an inch to four inches in diameter, to receive the necks of retorts, flasks, and receivers. Between the shelves should be fixed various hooks and nails to hold and retain tube apparatus, such as siphons, detonating tubes, tubes of safety, &c. One cupboard shelf should be particularly appropriated to receive products of experiments in progress which have to be preserved for a few days (1302); or things which, being valuable, are but rarely required, as potassium, &c.

15. All parts of the walls of the laboratory within reach, conveniently situated, and not otherwise occupied, should be fitted up with shelves in a firm manner, to receive bottles and jars. These must vary in strength, size, and interval, according to their intended uses; such as are to hold the bottles containing the usually extensive and continually accumulating series of chemicals, need seldom be of greater height or depth than to receive a six or eight ounce phial standing close against the wall. Those intended for the jars of the pneumatic trough must be wider and at greater intervals; and those, again, which are intended to hold the stock-bottles must be considerably stronger, in consequence of the weight to be borne by them. In arranging the shelves, it will be proper to pay attention to their situation: the first series, for instance, containing the chemicals and

tests in constant use, should be near the table upon which operations are most generally carried on, whilst the stock-bottles may be put upon shelves considerably out of the way. A shelf near the sink, with holes in it, upon which apparatus which has been washed and rinsed may be placed to drain, is very useful; and two or three others in the same neighbourhood, or somewhere out of the way, supply places for chemical lamps, oil-cans, and other dirty articles that cannot but exist in a laboratory.

16. Retorts are very conveniently preserved by being hung on wire rings from an inch to an inch and a half or two inches in diameter. These are easily made out of copper wire, and being screwed or fastened in a row into a wooden partition, receive the necks of the retorts, and hold them in a very safe, compact, and convenient manner. The advantage is obtained, also, of seeing the whole stock of retorts at once, and instantly choosing that best fitted for any required purpose.

17. Analogous in its office to the shelves, is the tube-rack; it is intended to hold pieces of glass tube from one to four feet long, and generally consists of a shelf about three feet long and from six to eight inches wide, having a piece fastened on the front so as to form a raised edge about an inch high: or it might be made with some advantage by driving three or four long pins or holdfasts into the wall in a line, the end of each being turned up. No wooden bottom is in this case used, and the piece of glass tube required is more readily selected from among the rest, than when upon a rack of the former kind; the smaller pieces are, however, apt to fall through.

18. A part of the wall should be selected to be furnished with long spikes, either by driving them into the brickwork, or fastening up a board to which they are attached. These serve to hold retort and flask rings, and large bent tubes, such as siphons, curved pieces, &c.; smaller spikes will answer a similar purpose for the numerous coils and pieces of wire that are continually required.

19. One or two large wooden blocks will be found useful in a laboratory; they may serve as bases on which to place

heavy mortars, and one of them will form a good support for a spike or anvil. They should have their appointed situations on the floor.

20. A set of ten or twelve small blocks of wood, about four inches square and of different thicknesses from half an inch to three inches, are also of great service in supporting parts of apparatus at different heights.

21. Some consideration must be given in appointing the places of the various pieces of apparatus and furniture in most common use; and their relation to the tables, the bottles, and each other must be taken into account. The pneumatic trough (727) is in constant service, and must not therefore be situated in a dark place, or far from the centre of activity: access to it should be ready, and communication from other parts open and free. The jar shelves (15) should, if possible, be placed near. The mercurial trough already mentioned as standing upon the table (12) should be similarly circumstanced. The table blow-pipe (242) is a very essential article, and in continual use: it should have a place against the wall near to its appendage, the tube-rack. The dirty, but useful coal-box should have a convenient, but low and unobtrusive situation given to it, that it may fully perform its part without interfering with the uses or advantageous situation of other things. It can hardly be imagined without experience how much is gained by an attention to these details; for though an operation may, either from its desultory nature or its subordinate character, be of little consequence when considered separately, yet when it has to be repeated again and again, and from its recurrence is continually entering into the business of the day, it attains a degree of importance which makes its ready and accurate performance of the greatest consequence.

22. The necessity of such things in the laboratory as flasks, retorts, receivers, bottles, phials, mortars, &c., will be evident, but any information respecting them will be most advantageously given hereafter. They are better supplied as they are wanted, rather than by a previous order; and in that way the accumulation of what is unnecessary is to a great extent avoided.

23. But there are other things, properly denominated tools, which, being always useful, should be immediately procured. Amongst these, an anvil or spike, with its foot-block, should stand on the ground, and a vice should be fixed against one of the tables. Two or three hammers, including one intended for mineralogical purposes, some cold chisels, a screw-driver, a saw, cutting chisels, gimlets, brad-awls; half-round, flat, and small three-square files; half-round, flat, and rat-tail rasps; pincers, pliers, forceps, a trowel, a soldering-iron with its appendages, are the tools which, with a glue-pot, and a collection of nails and screws, will be found necessary: and to these may be added a saw-knife for cutting soft brick; coarse spatulas, either of wood or bone, or made from iron hoop; and a cork-screw.

24. There are several articles which may be considered as materials in a laboratory. Bricks are often wanted to build up temporary furnaces, or to form supports: mortar is consequently useful; sharp river or sea-sand is required for sand-baths and other purposes, and is readily obtained from the bricklayer. Corks are useful in a thousand ways (1331), and should be provided of good quality, and of all sizes from a large bung downwards: old cards are extremely convenient. Matches, string, and bladder are necessary.

25. Many of these useful articles are best preserved in drawers, and hence the necessity of a number of these receptacles in a laboratory. If the tables do not supply enough of them, it will be desirable to have a strong rough set exclusively for these purposes. The appropriation of drawers requires some method: one should be appointed to receive fragments of glass tubes too small to remain in the tube-rack; another should be kept exclusively for the reception of those useful laboratory vessels, glass tubes of various sizes closed at one end (910); another, from containing corks, will be the cork-drawer; another, the tool-drawer—the files and rasps, however, being, from their quantity and general use, worthy of a drawer to themselves; the round glass plates, stirrers, and tapers, used in the laboratory, will also occupy a drawer; string, with

bladder and sand-paper, another; and tow, with dusters, another; drawers being the most convenient places for these things. One drawer should be divided within into various compartments intended for different small apparatus, as blow-pipes, forceps, a scratching diamond, platina foil and wire, &c.

Besides drawers, a few small strong wooden boxes are convenient in a laboratory, for containing lime, lute, manganese, sand, &c.; and a few wooden trays, with low rims, are exceedingly serviceable for removing apparatus.

26. *Distilled water* must be included among the chemist's requisites; and so much advantage is gained by its abundant supply, that any accessible source should be eagerly sought. Distilled water in large quantities is by no means uncommon in towns, for, in consequence of the numerous applications of steam, the opportunities of collecting it are frequent. Wherever steam is used for the conveyance of heat through pipes, the condensed water may, with a very little contrivance, be collected in abundance, by placing a clean cask or vessel under the place where it issues forth. Such water must of course be tested to prove its purity; that being rejected for laboratory use which from any derangement in the pipes or other circumstance is found to be impure. Where the laboratory cannot be supplied in this way, the water must either be bought or distilled (424); the furnace before described (8.177) is extremely well adapted for the application of a still for this purpose. Distilled water is best preserved for table use in a bottle holding about a quart, or three pints, which should be quite distinct in its form or appearance from any other bottle in the laboratory, so that no mistake respecting it may at any time arise.

27. An eupyron, or some other ready means of obtaining fire, should always be conveniently placed in the laboratory, and near to it a candle and candlestick. For the eupyron may be substituted the phosphorus bottle, made by stirring a piece of phosphorus about in a dry bottle with a hot wire; the phosphorus undergoes partial combustion, and forms a highly combustible coat over the in-

terior: a common sulphur match rubbed against the inside of the bottle, and drawn out into the air, immediately inflames; or if it should not do so, a second stir with the hot wire, or two or three days' rest, will generally render the bottle a good one. It should be closed by a glass stopper so as to prevent access of air, except at the short momentary intervals when it is in use.

28. There remains little besides to perfect the preliminary furniture of a laboratory. A blank writing-paper book should be upon the table, with pen and ink, to enter immediately the notes of experiments (1290). A chair may be admitted, and one will be found quite sufficient for all necessary purposes, for a laboratory is no place for persons who are not engaged in the operations going on there.

29. Having thus described the laboratory, it will easily be understood that great advantages would arise from the association of another room or two with it, which, nevertheless, may be dispensed with. A good balance is a very delicate piece of apparatus, and is soon injured and deranged if exposed to the attacks of the damp and corrosive vapours that are continually floating about in the laboratory, in which it should therefore be allowed to remain as little as possible, and yet from its constant use should not be far removed. If there be a small dry room at hand, it will be very convenient generally to keep the balance in it; and there the air-pump and its receivers, the electrical machine, Leyden jar, and a quantity of delicate apparatus, will usually be its companions.

30. On the other hand, such things as lute, sand, charcoal, coke, bricks, crucibles, voltaic troughs, carboys, &c. do not require a dry place, and would even cause injury if retained in the same room with the balance; yet it is advantageous, if otherwise convenient, to remove them from the laboratory into a separate place, that the former may be left unembarrassed and clear for operations. These, therefore, would go very properly into a dry cellar or covered shed, or any place that would suit as a rough lumber-room. Still it may be observed, that these places are not essential; and where the laboratory establishment is but

small, all the delicate apparatus may be put into a dry cupboard, and the other things find their situation in the laboratory itself.

31. It was once intended to annex a plan of a convenient and complete moderate-sized laboratory, but the idea was resigned, in consequence of the difficulty of exhibiting the important parts in more than one case out of ten. There will scarcely be two of these chemical workshops which may not advantageously differ in the arrangement of some of their essentials, as well as in the extent of their different parts; some being extensive in one department, others in another. A notion of the most necessary furniture of a small laboratory, or of one to be comprised, in cases of necessity, on the surface and within the drawers of a single table, may easily be gathered from the manipulatory parts of the present work. If the want of time, or other circumstances, should necessarily limit the chemical pursuits, the author would advise a person so situated to begin by providing a spirit-lamp, a blow-pipe, a pair of pliers, some platinum foil and wire, a platinum capsule, a few Florence flasks, a chemical lamp, a few evaporating basins, a few pieces of quill glass tube, and two or three dozen bottles; with some of the most useful chemicals, as the acids and alkalies, and six or eight of the most important tests; and to purchase all other things as the necessity for them may arise.

SECTION II.

BALANCE, WEIGHING, &c.

32. ON entering upon a part of this work which relates more directly to manipulation than the matter of the preceding pages, it may be proper to state very distinctly, that the object is not to give information relative to the nature or construction of chemical apparatus in general, but to teach its simplest, most effectual, and accurate use. It will be the endeavour of the author to keep all in strict subordination to this object; and when he enters into the con-

struction and principles of an instrument, it will be solely with a view to the clear comprehension of the manner of using it. Hence a reason for the apparent disproportion which will now and then appear in the details of this subordinate and descriptive part: for whatever the pupil or chemist can himself do towards the correction or construction of an instrument will be described, whilst that which must, of necessity, be done by the workman will be passed over in silence. To teach a person how to make a balance, or to inform him how it is made, is not the object of the writer; whilst, on the contrary, its use is the very point in view: whatever, therefore, facilitates the latter, or whatever can be done to correct slight derangement, by one who is not a workman, ought now to claim our attention.

33. A chemist cannot do without a delicate balance: it is absolutely necessary to his repetition of the most important experiments of others, or to his own independent progress. If he be an active operator, he will require two or three balances; for the weights with which it is necessary to work are almost without limit, and cannot be estimated by the same instrument. Large quantities, if weighed in balances competent to show minute differences in small weights, would, by flexure of the beam or change in the points of support, infallibly injure or even destroy them; and small weights cannot be appreciated in instruments intended for great quantities, because of the strength it is necessary the latter should have, and the consequent weight and comparative roughness of the parts. One pair of scales should therefore be provided that will weigh from one ounce up to three or four pounds, or even more, and be so constructed as to turn with two or three grains, when loaded with their greatest weight. They can, when required, be made very delicate and correct, but, except in particular cases, that is not necessary. Another balance, calculated to weigh from half a grain to two or three ounces, with considerable accuracy, and turning with about one-half or one-third of a grain when fully loaded, should be kept for laboratory purposes. This is intended for common use; and as it is a great object to save the superior in-

strument from injury occasioned by too frequent use, and to preserve it from exposure to the vapours which are constantly escaping in the progress of operations, or from the bottles, this should be substituted as often as possible for the latter, especially in cases which require the balance in the laboratory. The third, or choice instrument should be sufficiently delicate to weigh from 600 to 1000 grains and downwards, indicating distinctly and certainly differences equal to the $\frac{1}{100,000}$ or $\frac{1}{100,000}$ part of the weight in the scale.

34. The materials and construction of balances vary so much, as also do the circumstances which influence their purchase, that no general directions on this point can be well given. Whether large or small, they are best on fixed supports, and not suspended loosely, although very good ones of the latter construction are made. They should be preserved from all damp and vapours; and the beam of the large one, if its construction will admit of it, and even of the next pair, frequently oiled and wiped. The more delicate instruments should be cleaned by the maker: much harm is sometimes produced by rough and hasty cleansing; and if, when about to be used, it is seen that a spot arising from rust, or corrosion, or any other cause exists on the beam or pan of a delicate balance, it is better to compensate for the difference of weight it occasions, by adding a temporary counterpoise to the pans, than to try to remove it previous to the operation. If the balances are so constructed as to pack into boxes or cases, they should be kept in such cases when not in use. Delicate instruments are always inclosed in cases, and are so fixed in them as to require and admit of their use without removal. When not in use, the cases should always be closed. A loose green baize or linen bag to throw over the balances when in the laboratory, and not in use, is serviceable; and whenever of necessity the delicate balance is brought into the laboratory, it should be returned to its proper situation immediately that it is done with. The instrument itself is so expensive, so soon suffers injury, and then has its value and use so rapidly diminished, that every care should be taken to preserve it in efficient order.

35. The weights for these balances are as various as the instruments themselves. They will be wanted from 3 lbs. down to the hundredth of a grain, and will form at least two sets, the one consisting of avoirdupois pounds, ounces, and drachms, and the other of grains, from 1000 down to the minutest fractions. It is usual to construct these weights in sets, containing as few as possible in each. Thus 4 weights of 1, 2, 3, and 4 grains are sufficient to weigh from 1 to 10 grains, and with similar weights of 10, 20, 30, 40, 100, 200, 300, and 400, will weigh up to 1100 grains. The weights might be still further diminished in number by using such as are expressed by the following series 1, 3, 9, 27, 81, 243, and a series of twelve so constructed would weigh any number from 1 to 265,720; but this is not at all desirable in practice. Several of each particular weight, or several sets of weights, should be in use at once. This will not be necessary with the pounds, ounces, and drachms, because they are comparatively but seldom used in the laboratory, but with the grain weights it is required: for it is desirable, in all possible cases, to refer to the same kind of weights for simplicity of calculation and comparison, and grain weights being those generally and conveniently referred to, it follows necessarily that such are in constant use: this being the case, all delay or difficulty arising from a deficiency of weights should be avoided by an abundant supply. It frequently happens, that in the estimation of a loss or gain of weight, or in taking specific gravities, two or more weights of the same value are wanted; and this, together with occasional losses, will render it evident that there should be a liberal extra quantity. For this reason a small box, divided into compartments, containing a variety of grain weights, from a tenth up to 1000 grains, and intended to accompany the balance ordinarily in use, is exceedingly convenient. It is well to have a perfect set, from 500 downwards to the hundredths of a grain, to be always kept with the best balance, there being two or three sets of the fractions of a grain. Repetitions of those above a grain are in this case not required, but may be supplied, when wanted, from the laboratory-box.

36. These weights are sometimes made of brass; the smaller ones, however, are commonly of platinum. The fractions of a grain should always be of platinum, and it would be much better if that metal were constantly used for weights not surpassing 10 grains. Perhaps its expense for heavier weights would sometimes be objectionable, but this is fully compensated by the unchangeableness of the weights either from oxidation or corrosion, and the facility with which they are cleaned from ordinary dirt, either by slight wiping or momentary exposure to the flame of a spirit lamp. Where expense is no object, all the weights should be of platinum, their permanent correctness compensating abundantly for the increased cost.

37. If platinum be not used, there is probably no common metal better than brass, of which to construct weights; the larger grain weights, and also the pound series and its divisions, may be made of this alloy. It is liable to be affected very materially by the laboratory fumes, and in consequence small weights constructed of it are often rendered useless in a very short period. Keeping them in a close box retards this kind of injury. The pound and ounce weights are frequently constructed in sets, each weight being hollow, having the form of a truncated cone, and fitting into the others, so as when arranged together to form a solid mass. Such weights are very convenient in arranging counterpoises, the cup form enabling the largest weight used to receive all the additional matter required to make the counterpoise accurate, as will be seen in the practice to be described hereafter (64).

38. The laboratory-box of grain weights should include a pair of small brass pincers or forceps, for the divisions of a grain (54). The latter are too minute to be moved expeditiously and safely by the hand alone; and unless the weights be comparatively large, the handling of any of them is liable to communicate extraneous matter, and thus render them more or less inaccurate.

39. Associated with the weights should be some convenient substances for the purpose of counterpoising crucibles, capsules, tubes, &c. (64). A little box of clean shot of different sizes, mixed together, answers this purpose in

part very well; and its contents may be completed by a few pieces of thin sheet lead or tin foil.

40. The balance and weights should be carefully examined at intervals, to ascertain their accuracy, for if they involve unnoticed errors, the experiments made with them may be worse than useless. Some curious conclusions, tending to subvert most important chemical truths, might be quoted as having arisen solely in this way.

41. The theory of the balance is so simple, that the tests of its accuracy will be easily understood, and as easily practised. It may be considered as an uniform inflexible lever, supported horizontally at the centre of gravity, and supporting weights at equal distances from the centre, by points in the same horizontal line with the centre of gravity. If the weights be equal, the one will counterpoise the other; if not, the heavier will preponderate. In the balance, as usually constructed, there are certain departures from the theory as above expressed—some from the impossibility of execution, and others in consequence of their practical utility; and a good balance may be said to consist *essentially* of a beam made as light as is consistent with that inflexibility which it ought to possess, divided into two arms of equal weight and length, by a line of support or axis, and also terminated at the end of each arm by a line of support or axis intended to sustain the pans. These three lines of support should be exactly parallel to each other, in the same horizontal plane, and correctly perpendicular to the length of the beam; and the plane in which they lie should be raised more or less above the centre of gravity of the beam, so that the latter should be exactly under the middle line of suspension. It will be unnecessary in this place to speak of the coarse faults which occur in the ordinary scales—these will easily be understood; and from what has to be stated of the examination of the most delicate instrument, the impossibility of avoiding them without incurring an expense inconsistent with their ordinary use, will be as readily comprehended.

42. It will be easily understood that a beam constructed with knife edges resembles the one before mentioned, and

being supported on horizontal planes by the central line of suspension, as is generally the case, will take a horizontal position, in consequence of the situation of the centre of gravity. The addition of the pans causes no change in this ultimate position of the beam, because they are of equal weights. The delicacy of a balance depends very materially upon the relative situations of the centre of gravity, and the lines of support, *i. e.* the middle and the extreme lines of suspension. If the centre of gravity be considerably depressed below the fulcrum, then, upon trying the oscillations of the balance by giving it a little motion, they will be found to be quick, and the beam will soon take its ultimate state of rest; and if weights be added to one side, so as to make it vibrate, or turn as the expression is, or else to bring it to a certain permanent state of inclination, the quantity required will be found to be comparatively considerable. As the centre of gravity is raised, the oscillations are slower, but producible by a much smaller impulse, the beam is a longer time before it attains a state of rest, and it turns with a smaller quantity. When its situation coincides with the fulcrum or centre of oscillation, that also being in the plane joining the two extreme lines of suspension, then the smallest possible weight will turn the beam (supposing the knife edge and suspending plane perfect), the oscillations no longer exist, but one side or the other preponderates with the slightest force; and the valuable indication which is furnished by the extent and velocity of the vibrations is lost. The case where the centre of gravity is above the fulcrum rarely if ever occurs: such a balance, when equally weighted, would set on the one side or the other, that side which was in the slightest degree lowest tending to descend still lower, until obstructed by interposing obstacles; unless, indeed, the fulcrum was placed considerably above the line joining the extreme points of suspension, in which case the weights in the pans might counteract the effect dependent upon the elevation of the centre of gravity. In balances intended to carry large quantities, it is necessary to place the centre of gravity lower than in those for minute quantities, that they may

vibrate regularly and readily; and hence one cause why they are inferior in delicacy, for, as a consequence of the arrangement, they will not turn (or indicate), except with a larger weight.

43. The vibrations of a balance vary with the quantity of matter with which it is loaded; and the more the weight in the pans, the slower their occurrence. These should be observed, and the appearances retained in the mind, in consequence of the useful indications they afford in operations of weighing. A certain extent and velocity of vibration would indicate to the person used to the instrument nearly the weight required to produce equilibrium; but the same extent and velocity, with a weight much larger or smaller, would not be occasioned by an equal deficiency or redundancy of weight, as in the former case. The weight required also to effect a certain inclination of the beam, or to turn it, should be known, both when it is slightly and when heavily loaded. If the instrument turns with $\frac{1}{100}$ of a grain when 600 grains are in each scale, or with $\frac{1}{10000}$ of the weight to be estimated, it may be considered as very good.

44. Balances are sometimes liable to *set*, as it is called, when overloaded. The effect consists in a permanent depression of that side which is lowest: thus, if a balance be equally weighted in each pan, but overloaded, it will, if placed exactly horizontal, remain so; but the slightest impulse or depression on one side destroys the equilibrium, the lower side continues to descend with an accelerated force, and ultimately remains down, being, to all appearance, heavier than the other. Generally speaking, the more delicate a balance, the sooner this effect takes place, and hence one limit to the weight which it can properly carry. This setting of the balance, and the general diminution of delicacy by increase of weight, should be carefully kept in mind. The setting is considered as dependent upon the position of the fulcrum, *below* the line which joins the extreme points of suspension of the beam; the effect which would thus be produced being masked for a time by the centre of gravity in the beam falling below the fulcrum.

45. When the beam, freed from the pans, but supported on its stand, has been found to oscillate with regularity, and gradually to attain a horizontal position of rest, it should be reversed, that is, taken up and turned half-way round, so as to make that arm which before pointed to the right, now point to the left. The beam should then again be made to oscillate; and if it performs regularly, as before, finally resting in a horizontal position, it has stood a severe test, and promises well. The faults which are likely to be disclosed in this way depend upon imperfections in the work of the middle knife edge and the planes upon which it rests. The edge is made either of agate or steel, and should be formed out of one piece of matter, and finished at once; every part of the edge being ground upon the same flat surface at the same time. In this way the existence of the two extreme or bearing parts of the edge in one line is insured; but when the two parts which bear upon the planes are formed separately upon the different ends of a piece of agate or steel, or, what is worse, when they are formed on separate pieces, and then fixed one on each side the beam, it is scarcely possible they should be in the same line, and, if not, the beam cannot be correct. These knife edges usually rest upon planes, or else in curves. The planes should be perfectly flat and horizontal, and exactly at the same height; the curves should be of equal height, and their axes in the same line. If they are so, and the knife edge is perfect, then the suspension will be accurately on the line of the edge, and reversing the beam will produce no change.

46. When the pans are hung upon the beam, the balance should of course still remain horizontal. The lines of suspension for the pans are not so difficult to obtain correctly as that before spoken of; but they should be tried by changing the pans, then by reversing the beam, and afterwards by changing the pans again. The irregularities which may in this way be discovered in a balance can be corrected only by the workman, and are always difficult points in the final adjustment. Faults may exist in a slight degree in a very excellent instrument, and the inaccuracies

which might result from ignorance of them may be avoided, when they are known, by attention to directions.

47. The arms should in length and weight be equal to each other: the length of each is accurately the distance from the middle to the distant knife-edge, all the edges being considered parallel to each other, and in the same plane. The two arms should accord perfectly in this respect; but the weight is by no means necessarily subject to equality, though it is better that it should be so. One arm, with its pan, may be considerably heavier than the other, but, from the disposition of the weight in the lighter arm towards the extremity, or in the heavier towards the middle of the beam, the equilibrium may be perfect; and, therefore, no inaccuracy be caused thereby in the use of the balance. Instruments are usually sent home in equilibrium, and require no further examination as to this particular point than to ascertain that they really are in adjustment; and that, after vibrating freely, they take a horizontal position. If they should not do so, the fault is easily corrected for the time by a small counterpoise.

48. Equality in the length of the arms is much more important, and may be ascertained in two or three ways. Suppose the balance with its pans to vibrate freely and rest in a horizontal position, and that, after changing the pans from one end to the other, the balance again takes its horizontal state of rest. In such a case an almost certain proof is obtained of equality in the length of the arms. They may, however, be equal, and yet this change of the pans from end to end may occasion a disturbance of equilibrium, because of the unequal distribution of weight in the beam and pans: but, to insure an accurate test, restore the pans, and consequently the equilibrium, to the first state; put equal, or at least counterpoising, weights into the pans, loading the balance moderately, and then change the weights from one pan to another, and again observe whether the equilibrium is retained: if so, the lengths of the arms are equal.

Tests of this kind are quite sufficient for the purpose of the chemist; who, having ascertained that his balance, whe-

ther slightly or fully laden, vibrates freely,—turns delicately,—has not its indications altered by reversing the beam or changing counterpoising weights,—may be perfectly satisfied with it, and leave the fuller consideration of the difficult points and corrections to the instrument-maker.

49. The weights should undergo an examination as well as the balance, and it is necessary to make this with reference to their accuracy when new, and also to their change by wear or corrosion. It is essential in the first place to set out with a good standard, and though this point is of necessity generally left to the workman, yet, when possible, it is very desirable that the 1, 10, 100, and 1000 grain weight should be compared with others of good authority. The most ready method of detecting errors in the subdivisions is to make up equal quantities from different weights, and compare them together in the balance, a large one being tried against eight or ten smaller, as the 100-grain weight against those of 40, 30, 10, 8.5, 4, 2, and 1; and then again, from a quantity made up of several, to remove some and replace them by others, as, for instance, for the 30-grain weight above, to substitute a 10 and four 5 grain weights. The fractions of the grain should be examined in the same manner, and, if any material error exists, it will thus readily be discovered. Should the balance in use be one which, from accident or other circumstances, is affected in its indications by changing the weights in the pans, then, in these trials, all the changes should be made in one pan only, the weight in the other being considered as a mere counterpoise, and left undisturbed from first to last. The trials with those weights which accompany the best balance, and are intended exclusively for very delicate experiments, should be made with extreme care.

50. The examinations which are to take place at different periods, to ascertain the continued correctness of the weights, are to be conducted in a similar manner, except indeed when there is reason to suspect the alteration of a particular weight, which will then of course be tried against one admitted to be correct. These trials should be more or less frequent according to the exposure of the weights; those

which, from being continually in the laboratory, rapidly change their colour and appearance, will often require examination; but platinum weights are in this respect unalterable, and are liable to very little derangement of any kind from ordinary use.

51. The operation of weighing is very simple, and it is only because in the hands of the chemist it becomes one of extreme delicacy and frequency, that the facilities for its performance require to be mentioned. It should in the first place be ascertained, before every operation, that the balance is in order, as far as relates to its perfect equilibrium and to the freedom of vibration; and also that no currents of air are passing through the case, so as to affect its state of motion or rest, a situation being chosen where such influences may be avoided. If from any accidental cause it be not in equilibrium, it should be balanced by a fragment of paper, or a slip of tin or lead foil. If its vibrations are imperfect and impeded, the cause, whatever it be, must be discovered and removed, or a delicate weighing cannot be performed.

52. When the substance to be weighed consists of one or a few pieces only, it is merely necessary to put it into one pan, and to add weights to the other, until the two are in equilibrium. A delicate balance is always furnished with means of supporting the pans, independent of the beam; and the beam itself is also supported, when required, by other bearings than its knife-edges; and in such a manner as to admit of the rapid removal of these extra supports, that the instrument may be left free for vibration. This is done that the delicate edges of suspension may not be injured, by being constantly subjected to the weight of the beam and pans, and that they may suffer no sudden injury, from undue violence or force impressed upon any part of the balance. When, therefore, a large weight of any kind is put into, or removed from, the pans, it should never be done without previously supporting them by these contrivances: for the weight, if dropped in, descends with a force highly injurious to the supporting edges; or, if a large weight be taken out without first bringing the pans

to rest, it cannot be done without producing a similarly bad effect. No weight heavier than a grain should be introduced without this precaution, which, besides being requisite for the reason described, is otherwise advantageous.

53. When a weight is put in which is assumed to be nearly equal to the substance to be weighed, the balance should be brought to a horizontal state of rest, this being usually done by the same means as those appointed to support the pans; it should then be liberated gradually, so as to leave the pans wholly supported by the beam. The whole being upon its true centres of suspension, it will be observed whether the weight is sufficient or not, and the rapidity of ascent or descent of the pan containing it will enable a judgment to be formed of the quantity still to be added or removed (43). Bringing the balance to a state of rest as before, such quantity should be added, and trial again made; and it is better to repeat this for every required alteration of weight, however small it may be, than to endeavour to adjust the weight, whilst the whole is suspended from the knife-edges, and the pans are swinging in the air.

54. As the weight approaches to equality with the substance to be weighed, the oscillations become slow, and the beam ultimately rests in a line more or less inclined, being the same with that above and below which the oscillations are made. The position of this line may be judged of, therefore, whether the balance be at rest or in motion, and is a material indication of the weight to be added or taken away; a person who, from observation of the oscillations of a balance and the position of this line, is able to take advantage of the indication it affords, will effect the required equilibrium in three or four trials, when another person, unobservant of these points, will not do it in less than ten or twelve. The small weights should always be removed by a little pair of pincers (38), for when the fingers are used there is frequent risk that they may leave something adhering to the larger weights in the pan, or may brush out the smaller. The weights are safer too in pincers than in the fingers.

55. It sometimes happens that the balance appears to vibrate with difficulty, or to stick, though no sufficient cause can be discovered. On these occasions a slight tremor given to the instrument, by tapping on the case, or by a vibratory motion, will frequently assist the balance, and confer sufficient delicacy to allow of the operation being completed. The weight should always be estimated when the instrument is at rest, but it should be carefully ascertained by the freedom of vibration that this rest is the consequence of perfect equilibrium, and not due to the want of delicacy in the instrument or to accidental obstruction.

56. When the balance has ultimately been brought into a state of equipoise, the weight is next to be estimated. The operator generally takes an account of the additions and subtractions as he proceeds, but the resulting quantity should be confirmed by inspection. Remove the weights, therefore, from the balance, and if there be many, and especially small ones, this is best done by slipping them all out of the pan together into a small basin, or upon a sheet of paper, and then, by laying them out, their amount may be ascertained. To detect any error that may have arisen, either in calculation or otherwise, make up the quantity in other weights, the fewer the better; introduce these into the pan in place of the former, and see if they also accurately counterbalance the substance weighed: if they do, the accuracy of the weight is insured; if not, the cause of the discrepancy must be sought for, discovered, and corrected.

57. When the operation of weighing has to be repeated frequently, as happens in certain parts of analytical processes, it economises time to have the smaller weights arranged in order before the balance; the hundredths together on the right hand, then the tenths, then the grains below ten, and ultimately the large weights.

58. In weighing substances that are hot, great attention should be paid to any effect produced by the ascending current of air in elevating the pan containing the hot material, and thus giving erroneous results: a silver capsule, weighing 600 grains when cold, appeared to weigh less by seven-tenths of a grain when heated by a spirit lamp, and

again placed in the scale. If it had previously contained ten grains of a substance to be subjected to such a temperature, a loss of about 0.7 of a grain would have appeared to take place, when actually none might have occurred. Besides this probable fallacy, the introduction of a hot substance or vessel into the pan is liable to affect the arm of the beam above, if delicately constructed, and cause derangement for the time merely by its expansion.

59. Although, when the balance is in perfect order, it is indifferent which pan receives the substance and which the weights, it is advantageous always to use the same pan for the same purpose. Attention to this custom is a correction to a certain extent for inequality in the length of the arms; for though in the latter case a difference must exist between the weight and its counterpoise to produce equilibrium, yet this difference is constant, and quantities increased or diminished in equal proportions will equally balance each other, so long as the contents of the pans are not changed. If then the weights are always put into one pan, the quantities weighed in the other will be in the same proportion as the weights, though not exactly equal to them; and the products of an analysis estimated thus would be as accurately known as if the balance had been perfect. But if, on the contrary, the products were put first into one pan and then into the other, they would sometimes be over-rated, and sometimes under-rated, and the differences would very soon, by accumulation, be irreferrible either to the weights or each other.

60. Attention will be required in practising this rule in cases where frequent alterations in weight are taking place. Suppose carbonate of lime, in a crucible, had been weighed in the substance-pan by weights in the weight-pan: if it were heated violently it would become quick-lime, and lose in weight, but this loss could not be ascertained correctly by returning the crucible and lime into the same pan it was in before, and then adding weights to make up the deficiency, but must be done by removing weights from the weight pan; and if a second alteration were effected in the weight, as by converting the lime into a hydrate or sulphate, that must also be estimated by weights added to the weight-

pan, no weights ever being mingled in the same pan with the substance, but every change in the weight of the substance being estimated in the one pan by a corresponding change of weight in the other.

61. When weighing powders, or moderately divided matter, it is better not to lay them at once on the pan, but upon some interposed substance. For this purpose, two slips or pieces of glass, or two watch-glasses, of equal weight, should be used, one in the weight scale, and one in the substance scale. They are easily preserved clean, and possess the advantage of generally resisting chemical action, and permitting the substance to be washed off them without injury. Or, in place of two pieces of glass, one piece, or a little Wedgewood's basin, counterpoised, will answer the purpose. But two pieces of paper are generally more convenient, and there are few substances which may not be weighed upon them. Hot-pressed wove paper is the best; its smooth surface preventing adhesion even of the finest powders. It should not be torn, but cut, for the fragmented edge would retain a portion of the powder when passing over it; its form is given and its adjustment easily made by a pair of scissors. Its flexibility is very convenient in assisting to convey powders into a flask, or other narrow-mouthed or small vessel. All these advantages are obtained by the use of a material, which has, in addition, those of being very cheap and clean, and the few cases in which it is objectionable, as where the substance to be weighed is moist or deliquescent, or warm, are easily distinguished, and its insufficiency may then be supplied by the use of glass or metal.

62. In transferring small quantities of powder from place to place, as for example into and out of the balance, and adjusting them, spatulas are very useful, and one of platinum, for this and other purposes, is requisite in every laboratory. It may be about half an inch wide, at least three inches long, and so thick as to resist considerable force without bending; otherwise it will not be the generally serviceable instrument it ought to prove. For those who are inclined to indulge in the luxuries of chemistry, a pocket-knife, with

a platinum blade, is a very excellent tool, answering many of the purposes of the spatula above described. With reference to the removal of powders, ivory and bone spatulas answer the purpose well; but in case of the absence of all these, their place at the balance may be supplied by a slip of the same hot-pressed wove writing-paper before mentioned, cut from the sheet with scissors. In effecting the ultimate adjustment of the quantity, the smallest portions may be taken by it from the heap in the scale, and by a slight lateral shake the smallest quantity may be dropped from it into the pan: copper and platinum foil do not make good temporary spatulas, unless bent in a line down the middle, for they are apt to give way between the fingers, and by their elasticity to scatter the substance.

63. It is not necessary in weighing out given quantities of powder, 100 grains for instance, to bring the balance to rest every time a little of the substance is added or removed, inasmuch as by a short practice both may be done without communicating any other impulse to the instrument than that resulting from the alteration of weight.

64. In using the balance, the operation very often consists merely in counterpoising, no estimate of the quantity being required, but simply an accurate and temporary weight corresponding to that of the substance or vessel. Platina crucibles, capsules, glass tubes, &c., either alone or with their contents, very frequently require to have their weights thus compensated; for counterpoises should be considered as weights, and go into the weight scale. If but a small one be required, a slip of tin foil, leaf lead, or even of paper or card, will answer the purpose very well, the piece being trimmed down by scissors till it balances the object in the other pan. If a larger one is wanted, a piece of plumbers' sheet lead is convenient, and may be accurately adjusted by a pocket-knife. Besides sheet lead, shot of different sizes (39) are often used for this purpose, being poured into the weight-pan until there is nearly sufficient to balance the contents of the opposite scale, and the final adjustment made by a piece of lead, or tin foil, or paper. When shot are not at hand, the counterpoise may be nearly

made up by large weights, and adjusted as before by metal foil. Where the whole consists of many parts, it is desirable that they should be preserved compactly together, lest any portion be dispersed, and inaccuracy introduced. The hollow weights (37) are for this reason very useful in counterpoising; the largest weight that is not too heavy should be taken, and the requisite addition placed within it. If such a convenience be not present, then perhaps the best plan is to put a piece of clean smooth paper (writing-paper if ready), of a few inches square, into the pan, in the first place, and add weights to complete the counterpoise; the ultimate adjustment can be made as before, or even upon the edge of the piece of paper: when that is done, enclose the loose portions of the counterpoise in the piece of paper, wrapping all up safely together, again see that it is accurate, and then set it aside in the drawer of the balance, or in the place appointed for such things, until it is required. In consequence of the change in weight of paper, either by desiccation in a dry place, or the absorption of moisture in a damp one, a counterpoise so wrapped up should be kept in a place similar in dryness to that from whence the paper came, and the chances of change are diminished as the time is less during which it is necessary to be preserved. When the mind is alive to this source of error, it is easily avoided, by keeping paper for the purpose in the place where counterpoises are kept, or by drying the paper and keeping the counterpoises also in a dry state.

65. Sometimes vessels or substances are to be weighed which will not conveniently rest in the pans without a little contrivance: tubes, if long, now and then interfere with the case containing the balance, and flasks are liable to roll over, occasioning the loss of their contents. Tubes of moderate length, such for instance as are used in the processes of organic analysis, can often in these cases be weighed by the use of a small loose loop or ring of twine, which, being slipped over the suspending wires of the balance pan, is to be raised nearly to the top, and then, by passing the tube through it, the upper part will be sup-

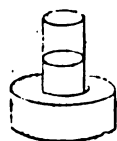


ported, whilst the lower end rests in the pan, the whole being in a position approaching to the vertical. In this case it is necessary that the loop and tube be arranged so that the latter does not touch the beam, or in any way interfere with the free suspension of the pan supporting it.

Such a loop is also very convenient in supporting flasks in the balance, for, being allowed to descend upon the suspending wires of the pan, it prevents the neck of the flask from passing between them, and retains it in a position sufficiently vertical to avoid the loss of any of its contents.

66. Many balances, in order to facilitate their various uses, have a hook at the bottom of each pan: to this a thread or wire is readily attached, and, being terminated beneath in one or more loops, is easily made to sustain a tube or other article to be weighed, which from its inconvenient shape will not lie safely in the pan itself.

67. When it is required to weigh liquids, they must of course be retained in some convenient vessel, the weight of the vessel being either known or counterpoised in the first place, or ascertained by an after operation. Glasses, flasks, capsules, and small tubes, are all useful in turn to retain fluids. The glasses and capsules will stand readily in the pan, and the flask may be supported as before mentioned (65) by the loop of twine, or by being placed upon a small wooden ring about two inches in diameter, and an inch wide, covered with list, which serves as a temporary foot (68). The tubes will more frequently be required to contain scarce fluids, or perhaps such as have actually been formed in them during an experiment, and will often require supporting. It is, for this and for many purposes of adjustment at the balance, convenient to have two rings of good cork, about three-quarters of an inch high, kept with it, fitting loosely into each other, and having, for the internal diameter of the smaller, half an inch, and for the external



diameter of the larger, two inches. These will support most tubes in a more or less inclined position; and in any case where they will not answer the purpose, a temporary stand is easily made out of a cork, by piercing a hole through it with a rat-tail rasp, of the proper size to receive the tube.

68. The listed rings referred to (67) are exceedingly useful in the laboratory for the support of retorts, flasks, globes, receivers, and all vessels of a circular form. They are easily made out of a slip of thin pliant wood, or a piece of sheet copper, the rough ring being covered by rolling list round it. A number of them should be provided for laboratory purposes, from two to six inches in diameter, and of different heights.

69. Where a certain weight of fluid is wanted, its final adjustment is easily effected by several methods. If it be water or alcohol, or a substance that does not act upon paper, it is best to add a little over-weight, and then to remove the excess by bibulous paper. If a piece of filtering paper be folded up several times in the same direction it will form a loose rod, the end of which, being dipped into the fluid, rapidly imbibes a quantity by its porosity and capillary attraction: when it has arisen about an inch in the paper, which it will do instantly, if the moist piece be pulled off and the fresh end again immersed, a second portion will be taken. Upon pulling off the moist end, especially if done by a hard pinch extending slightly over the dry part above, a ragged extremity is left, which, by a little management in dipping the paper into the fluid obliquely, may have a pointed form given to it. This may be used in removing either large or small quantities, and is very convenient for the final adjustment of the weight: by allowing only a few of the filaments which remain to enter the fluid, the latter passes up slowly, and its quantity may be judged of by the gradual progress of the moisture above; so that with very little trial the precise quantity required may be removed. Such at least is the case with water and most aqueous solutions. With alcohol, fixed and volatile oils, it is not so, because the imbibed part does not separate with particular facility from the dry portion, or leave the useful filamentous edge spoken of. The final adjustment is here, however, easily made by a slip of paper folded once or twice, or by other means to be described.

70. There is no difficulty in the rough adjustment of any fluid; for even when corrosive, the larger portions may be

removed by dipping into it a small capsule, or a spatula: in these cases the final adjustment may be completed by taking up the small remaining excess by means of a glass rod. Upon dipping a rod into a fluid and withdrawing it rapidly, holding it meanwhile in a horizontal position, as much as would be contained in three or four drops may be readily and neatly removed; the rod being cleaned, more may be taken away by the same process: as the quantity removed is proportionate in some measure to the moistened surface of the rod, it is evident that, by using one which is conical at the end, the smallest desired quantity may be taken up at once, and the adjustment accurately effected.

71. One other mode of adjustment it may be well to mention, leaving the many varieties which may be conveniently devised as occasion may offer, for spontaneous suggestion. It is sometimes necessary to weigh out a certain portion of a fluid, which, from being a new product or the result of a peculiar experiment, and small in quantity, will not admit of the slightest waste. A tube about the eighth or tenth of an inch in diameter, drawn out to a capillary termination, is then very convenient. If its fine extremity be immersed in the fluid, which we will consider as



in excess in the balance, capillary attraction causes a portion of it to enter the tube; if enough be not removed, by inclining the tube more will enter in consequence of the diminished perpendicular height of that within; if too much be removed by the second insertion, an elevation of the tube into a position more perpendicular will cause the passage of a portion from it into the vessel; and in this way more or less may be taken away and accurate adjustment obtained. Should the fluid be tardy in its motion within, from the dryness of the interior or smallness of the lower aperture, it may be helped while passing in or out, by applying the mouth of the operator to the upper orifice; but this should be avoided generally, lest any portion of moisture be introduced. When it is necessary to lay the tube down, it may be placed in a position nearly horizontal across a glass or ring (68), or any ready support, the lower small extremity

being out of contact with any other substance. When the operation is finished, the quantity which ultimately remains upon the tip of the tube, the only part that has at any time been immersed, is so small as to be no object, and this is the whole of the waste incurred. The portion remaining within the capillary tube is to be restored to what is left of the original quantity.

72. Peculiar management is required in estimating the weight of certain substances which rapidly undergo change, and are hence liable to alterations in weight during the time occupied in the performance of the operation. Suppose, for instance, it were necessary to weigh some hydrate of chlorine obtained by compressing the moist crystals produced at temperatures below 40° , within folds of cold bibulous paper; or that the weight of hydrated chloride of calcium in crystals, and dried in the same manner, by compression, were required; the first would evaporate in the air, and not only injure the balance and neighbouring bodies, but also lose weight; and the latter, by deliquescing, would gain weight; both with such rapidity as entirely to prevent the attainment of accuracy. These effects will be completely avoided by transferring them, not to the pan of the balance, but to a portion of water of known weight, and ascertaining the increase of weight so occasioned. In such a case, therefore, weigh or counterpoise a portion of water in a test glass or basin, and then, the crystals being prepared and dried by compression, transfer them rapidly to the water, and ascertain their quantity by the increase of weight: then proceed with the analysis or experiment, using the solution in place of the crystals. It is evident that an expedient of this kind has its limits, consisting in the nature of the experiment to be made, and the action of the water on the substances; but it is often very valuable, and now and then removes a difficulty which could not otherwise be surmounted. The choice of the substance which is to receive the changeable body must depend upon circumstances; and sometimes alcohol, sometimes water, and sometimes an acid, alkaline, or neutral solution, is to be preferred.

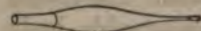
73. It may here be observed, that, as in many experiments one quantity is equally convenient with another, so that it be accurately known, we have the advantage in such cases of avoiding any trouble dependent upon adjusting accurately the quantity of matter, and obtain the same end by adjusting the weights, the matter itself being left undisturbed. Thus, if it were wished to know how much chloride of silver would be furnished by a given weight of crystalline hydrated chloride of calcium, 76.43, or any other number of grains, would answer the purpose as well as an accurate hundred, and the facility of immersing the body in water as above described is obtained. The particular cases where an opportunity of this kind, dependent upon the adjustment of the substance or the weight at pleasure, can be taken advantage of, must depend upon the judgment of the experimenter.

74. Similarly changeable products, the weights of which are required, are frequently produced in vessels, and especially in tube operations. In such cases the method will be to counterpoise or weigh the vessel and its contents, then to remove the substance, and, cleaning the vessel, to ascertain the loss of weight, that being the weight of the substance. Wherever such a course is necessary, the use of vessels that may be cleaned without injury or change is evidently needful: hence a great advantage of tubes and vessels of glass, or platinum crucibles and capsules.

75. Substances which fume, and which may in consequence cause injury to the balance, should be weighed in close vessels. Of such kind are some of the acids, ammonia, and numerous mixtures.

76. Small capillary tubes, made by drawing out a piece of thin quill glass tube at the blowpipe, as hereafter to be described (Sect. xx.), are exceedingly convenient for the estimation of minute quantities of valuable liquid products,

or moderately but not excessively volatile substances, such as ether, &c. : the tube



may be of the general form of that depicted in the woodcut, and of the same size, or larger, as may be convenient: having been counterpoised, it is to be charged with the

fluid to be weighed, by dipping into it the smaller extremity, and inclining the tube. When a sufficient quantity has entered by capillary attraction, the tube is to be withdrawn, the small portion of external moistened surface wiped, and the whole weighed, care being taken that the end does not touch any substance, for then the fluid may be drawn out. In this way the quantity can be accurately ascertained, and then, that the experiment may include all weighed, it will be found of advantage if the tube, being of no consequence to the result, may be thrown with its contents into the solvent, or added directly to the substance upon which the action is to take place: the tube itself being broken up and disregarded.

77. Sometimes it is desirable hermetically to close one end or even both ends of the tube charged as above: this is easily done by having it of the annexed form, the capillary termination



being rather wider than the part a little above it. In this case, when the tube is filled as far as is desirable, by inclining or inverting it, the surface in the narrow part will leave the extremity, and this, being introduced for a moment into the flame of a spirit lamp, will be effectually sealed: this done, the fluid is to a great degree secured and rendered stationary in the tube, and, if required, it is easy, by approaching the other end to a spirit lamp, to soften the glass, draw it out, and seal it, in the manner to be shown hereafter.

78. Where, in place of any particular weight, merely an equal, double, or triple quantity of one substance is wanted to be added to another, a convenient quantity of the one most worthy of consideration may be put into one pan, and counterbalanced once, twice, or thrice, by the other. In mixing dry substances, or in making analyses with reference to the kind rather than the weight of bodies present, this comparative mode of estimation is frequently useful.

79. In most processes of weighing, the buoyancy of the air is overlooked, and though, in consequence of the very superior density of solid and fluid matter generally, as compared to the atmosphere around us, errors thus introduced are usually unimportant, yet the chemist should be aware

of its influence, and alive to its possible interference. From the manner in which gases are usually weighed, the error does not then exist, but it is sometimes more considerable than would be expected in experiments made with substances at one time in the gaseous state, and at another in the liquid or solid form. The production of water, for instance, from the combination of oxygen and hydrogen, is an important experiment, and has been often repeated: the weight of the water should accurately correspond with the weights of the gases combined. The weights of the gases are in the usual method correctly ascertained, but the weight of the water estimated in the usual way is diminished by the buoyancy of the air, which in this case, amounting to about $\frac{1}{1125}$ th part, would introduce an error to that extent, were this effect not to be taken into account.

80. The determination of specific gravity is of constant occurrence with the chemist; and, though it resembles the general operation of weighing, there are peculiarities connected with it which require attention. It is not intended here to go into a consideration of the general process, but, leaving that to be obtained from elementary works, only to notice those things which occasionally give rise to errors, or are necessary to correct results. If the substance be a solid, the well-known process of weighing it first in air and then in water, and dividing the first weight by the difference between it and the second, is to be followed; and though here again minute errors are introduced in consequence of the buoyancy of the air in the first weighing, they are not of a nature to require attention in this place.

81. Balances are expressly furnished with contrivances to facilitate the immersion of the body in water, when required, so that its weight may be ascertained in that position. The substance which passes or cuts the surface of the water, supporting the immersed body and connecting it with the scale-beam, is generally a horse-hair, and for common purposes it is perhaps the best. When, however, a hydrostatic balance is not at hand, and an ordinary balance is to be used for the purpose, the suspending link has frequently to be selected from several substitutes which

present themselves in the laboratory. It should not be penetrable or alterable by the water; it should not be thick; it should not be weak. If it be the first, as a piece of thread for instance, the quantity of water in it undergoes continual variation in consequence of the difference of immersion as the balance vibrates, and thus a change of weight is occasioned in that which ought to be constant. If it be the second, as a piece of string, it introduces errors of two kinds, one dependant on the buoyant power of the water over the part which is sometimes immersed and sometimes not, and which if the same point were not always brought to the surface of the water would act upon it, as it would upon the stem of the hydrometer (103); the other dependant upon the capillary attraction of the water, which, within certain limits, would cause a larger elevation of the fluid round the string when thick, than if it were small, and add a proportionate weight to it. If it were the third, it would present an obstacle to the correction of the faults last mentioned, inasmuch as it would not admit of being made thin for want of strength.

82. These errors become serious when they affect a small body, a gem for instance; and in such cases, or wherever the weight will admit of its application, a filament of unspun silk is probably the best substance that can be used. It is unaffected by the water; has scarcely any weight, or any buoyancy given to it by immersion in the fluid, so minute is its bulk; it does not cause any sensible elevation of fluid round it where it cuts the surface of the liquid, and retains no air-bubbles. It has but little strength in consequence of excessive tenuity, and therefore must not be pulled hastily or subjected to sudden snatches.

83. When a silk fibre will not answer the purpose, or cannot be obtained, a fine wire will very conveniently supply its place; and it is only in cases of necessity that recourse should be had to thread, fine twine, or any substance made up of numerous fibres. But if some of the latter must answer the purpose, then silk thread is better than any other, because of its strength; and what is called thrown silk, which consists of a few fibres only, twisted

together, is, when strong enough, almost unobjectionable. In all these cases of substitution, take that substance which, being of sufficient strength, is the thinnest and most compact; and in all cases it is desirable that the mass of which the specific gravity is to be taken should be as large as the line will safely support: for if a coarse suspending thread be used with a small fragment, the errors due to the thread, which are several in number, affect the result much more importantly than if the operation had been performed upon a large piece.

84. There are several points relative to the immersion of the body in the water which require attention. The water must be distilled for delicate experiments; but on ordinary occasions, when that cannot be obtained, pure rain-water may be substituted, or in common cases even well or spring water of ascertained purity. Several wells are known, amongst which are the deep ones of London, which supply water as pure or purer than town rain-water. The temperature of the water and the substance to be examined should be the same, or otherwise currents will be produced, which to a slight degree affect the results: indeed, all delicate experiments must be made at one particular temperature, and 62° Fahrenheit is very convenient for the purpose. A considerable difference of temperature at different times prevents the results from being comparable with each other.

85. The body, as well as the various contrivances for its suspension, constructed by the instrument-makers, such as pincers, forceps, &c., must of course be fully immersed in the water. It should have at least half an inch of the fluid around it in every direction, that perfect freedom for the motion of the balance may be obtained. All bubbles of air adhering to it should be removed by a hair pencil. Water, taken from the bottom of any deep portion which has been exposed at the surface to contact with the air for a length of time, will frequently evolve bubbles, either spontaneously or upon the immersion of a rough substance, in consequence of its relief from the previously superincumbent pressure. Spring-water drawn from the bottom of a well

will illustrate this effect, which is very inconvenient when it happens with such water as is used for taking specific gravities, from the succession of bubbles produced. Exposure to the air for an hour or two, or pouring it to and fro in a broken stream several times in the air, is a remedy for the evil.

86. The oscillations of the balance, though much slower than those which occur when the body is weighed in air, should be quite free. Supposing the balance to be in good order, and the body suspended with perfect liberty in the water, neither touching any part of the vessel nor approaching the surface, still serious obstructions may exist, especially when the substance is small, the balance delicate, and the suspending line thick. Suppose a horse-hair to be used for suspension, which, from the manner in which it is wetted by the water, causes a small depression on the surface of the fluid around it as it descends, and a little elevation as it ascends. Such is a very common effect, and is produced not only on the first immersion and emersion of the hair, but is repeated at every ascent and descent, within certain limits. It is evident that this will very seriously retard the oscillations of a delicate balance, and prevent its motion either one way or the other by a force equal to the weight of the little elevation of water. This may be partly corrected by tapping the vessel containing the water, or the case of the balance, so as to occasion a slight tremor. Whenever it happens, the equilibrium should not be considered as obtained, unless the water have a plane surface at the part where it surrounds the hair.

87. The substance used as a support generally becomes wetted by immersion in the water; and in consequence of the extent of oscillation, a portion of the wetted part is constantly out of the water when the balance is poised. This affects the result in two ways: first by the water which adheres to the support, and which varies in proportion as it has been immersed to a greater or smaller depth, or as it is impervious to water like a hair, or more or less open like thread; secondly, by the little elevation of water which exists round the line by capillary attraction, and which is

the same whether more or less of the part above has been wetted. The weight of the water thus raised above the surface is counterbalanced by an equal weight in the opposite pan : thus an error to that extent is introduced, which, though generally small, may, from ignorance, inattention, or the minute size of the piece operated with, at times become important.

88. Although the suspending line may have been very accurately compensated in the air, before the body to be immersed in water was attached to it, yet when partly immersed during the progress of the experiment, the counterpoise is no longer its equivalent, the part immersed being buoyed up by a force equal to the weight of the water which it displaces ; and this, with a large horse-hair, or a still coarser line of suspension, would be important. It may be estimated, as well also as the effect of the little elevation of water before spoken of, after the weighing has been finished, by removing the body, again immersing the hair to the same depth as before, allowing it to be wetted to the same degree, and seeing how much it differs from its weight when freely suspended in a dry state in the air. Balances which are fitted up with apparatus for hydrostatical experiments have counterpoises for the suspending parts, both when in and out of the water ; which might be made perfectly accurate were the surface of the water always brought to the same place upon the suspending line.

89. All these errors are lessened by diminution in the size of the suspension line ; and when that is a silk filament, they almost disappear. Hence the great use of this substance in delicate experiments, as those made with small gems, minute globules of metal, or other rare substances.

90. When the substance of which the specific gravity is to be taken is soluble in water, some other fluid of known specific gravity must be used, which does not dissolve it. There are very few cases which may not be met by alcohol, oil of turpentine, or olive oil.

91. Not unusually, the body to be examined is porous like coke, or divided, as in sand or powders, into numerous parts. It may then be placed in a small glass or metal cup,

which is of course to be counterpoised first in air and then in water, exactly as was described with the line or retaining forceps before mentioned (85).

92. The specific gravity of fluids is ascertained by weighing equal bulks of them at the balance; or by the immersion of hydrometers or bulbs—bodies, which, by their floating or sinking, indicate the comparative weights of the substances into which they are introduced. Bottles are usually provided by the instrument-maker as measures of the bulk of fluid to be weighed; these are arranged to hold a given quantity of distilled water expressible by weight, in round numbers, as 1000, 800, 500, 280 grains, &c., and are closed by a ground stopper. The ultimate adjustment is effected by removing portions from the lower surface of the stopper, so that when the bottle is filled with water, and the stopper put into its place, the quantity which remains in, and entirely fills the bottle, is of the bulk required. The stoppers, instead of being solid, are sometimes made of a piece of thick thermometer tube of fine bore, the intention being to afford a free passage for the excess of fluid when the stopper is forced into its place. This answers the purpose very well with water and less volatile fluids, though it is not necessary; but with very volatile fluids, as alcohol, ether, &c., it occasions an evil. It does not merely afford a small surface for evaporation, but, in consequence of the impossibility of grinding a stopper so accurately that when in its place it shall not let a little of these limpid fluids pass, actually accelerates the evaporation: for the ether, for instance, passing by capillary attraction between the stopper and the bottle, evaporates round the edge, whilst the air enters in a constant succession of bubbles by the centre passage, and thus a rapid diminution in the bulk of the fluid takes place; whereas if the bottle had been closed by a solid stopper, although the minute ring of fluid round the top would evaporate, no more would be able to rise, because air could not enter to supply its place, and the bulk would be comparatively unchanged.

93. Specific gravity bottles are constructed of various sizes, and are each accompanied by a weight, which coun-

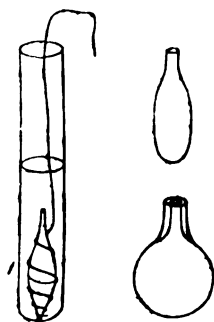
terpoises the bottle full of distilled water, the quantity of water required for the purpose having been ascertained and marked upon it. All that is required in estimating the specific gravity of any other fluid is, to fill the bottle with it, to ascertain its weight by observing how much heavier or lighter it is than the weight furnished with the instrument, and adding or subtracting accordingly: the result, divided by the weight of water, will be the specific gravity. It is necessary, in these experiments, that the temperature be observed, or rather, indeed, when convenient, that they be made at the same temperature, or it will not be possible to compare them unless previously corrected by calculation, which would in many cases be difficult. For the same reason it is requisite that the bottle should not be handled by uncovered hands, lest heat be communicated to it, and its bulk and the volume of the fluid within be affected: but, upon introducing the stopper, the overflow of liquid should be wiped off with a clean cloth, which may be used at the same time to prevent contact with the hands; and in transferring it to the balance, the fingers should be defended in a similar way: or if this be difficult, from any particular circumstance, they must not on any occasion touch more than the thick rim of glass round the stopper.

94. It is further necessary that the bottle contain nothing but the particular substance to be weighed. To insure this point, it is requisite that it be washed out after every experiment, the last two or three rinsings being made with distilled water: if it be then dried, nothing more remains to be done, upon the performance of a new experiment, than to put in the liquid and to weigh. But as it is inconvenient and unnecessary at all times to dry the bottle, as when the specific gravity of several solutions are to be taken in succession, it may, on such occasions, be left moist within; and then, at the next experiment, if the substance to be operated with is abundant, and one that mixes with water, as a mineral water, alcohol, or an aqueous solution, all that is necessary is, that the bottle should be rinsed with it two or three times before it be filled for weighing. If it be a sub-

stance that is scarce, or oily, or that will not mix with water, the bottle must be clean and dry.

95. Instruments procured from the maker should be verified by the purchaser before they are used. For this purpose the bottle and stopper should be well washed and dried, and, being brought to the temperature of 62° Fahrenheit, should be counterpoised. The bottle must next be carefully filled with pure water at 62°, and the increase of weight ascertained; this is the weight of the water, and should correspond with that marked on the weight or the stopper: finally, the counterpoise and water, weighed together, should exactly balance the weight sent with the bottle. If the maker graduates the bottles at any other temperature than 62°, it is useless to expect an exact accordance with estimates made at 62°, but he should always do it at a known and constant temperature, with which the purchaser should be acquainted; and that of 62° Fahrenheit is for several reasons better than any other.

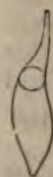
96. The directions given for the verification of a bottle made purposely for the estimation of specific gravities of liquids will easily enable a person to supply its want. He has but to select a small well-stoppered phial of convenient capacity, to clean, dry, and weigh it, and then to ascertain, as before, how much water it will hold: the weight of this water will be a divisor, and the weight of any other fluid filling it, a dividend; the quotient will be the specific gravity of the latter fluid.



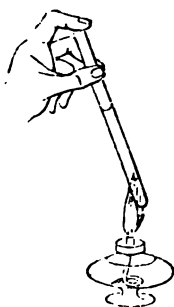
97. Small bulbs blown out of glass tube, or even small thermometer bulbs, like those figured in the margin, are often useful in estimating the specific gravity of rare fluid products. The little bulb represented in the tube is easily made, as is hereafter to be shown (1197); and having been counterpoised and furnished with a temporary handle, by coiling a piece of platina wire round it, may be warmed by a spirit lamp, and then dipped into the fluid in the tube: as it cools, a

portion will enter; upon removing, rewarming and reimmersing it, a second portion may be introduced by the same mode of proceeding; a small bubble of air will ultimately remain within, but this may be expelled by warming the fluid in the tube with the bulb immersed in the state in which it is represented in the engraving; the liquid will expand by the heat, and force out a part of the air; then by immersing the bottom of the tube in water to lower the temperature as contraction takes place, the fluid will enter the bulb. A second or third performance of the heating and cooling process will effectually fill the vessel with liquid.

98. The filling of bulbs in this manner is very often required in certain trains of research, and amongst others in organic analysis. Hence it is necessary to point out one or two circumstances requiring attention in the operation. When the bulb is about four-fifths full, and the attempt is made to fill it by applying heat whilst it is immersed in the liquid, it will perhaps be found that the bubble of air expands and contracts as its temperature changes, but does not go out of the vessel; the fluid which enters remaining,



by capillary attraction, in the narrower part of the top, and consequently passing out again upon the re-elevation of temperature. But in such a case it is necessary, before the heat is applied, to make this portion of the fluid and the air change places, which is easily done: for this purpose the tube, with its contents, should be held by the upper part, and suffered to hang as it were below the hand; a swing of a foot or two in extent should then be given to it, so as to produce centrifugal force; all the fluid will descend except that which is contained in the narrowest part of the neck, and the air will take its place; the tube and bulb should then be heated to expel more air, and fresh fluid suffered to enter, which is to be treated in the same way if required. If anything renders it inexpedient to subject the whole tube to this motion, the bulb can be withdrawn, and being held by the wire or in the hand, can then be shaken in the same way and with the same effect.



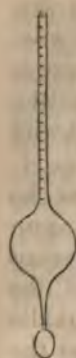
99. In the next place the fluid may be volatile, and subject to waste by repeated elevations of temperature in an open tube ; but in such circumstances it is easy to close the tube effectually by the fore-finger of the left hand, whilst the thumb and second finger are occupied in holding it (919) : the heating and cooling are then to be performed without allowing the end to be unclosed, and no waste is occasioned.

100. This point of manipulation will require a little practice to allow of all the advantage being derived from it which it is capable of affording in other operations ; but when required, a volatile fluid, ether for example, may be heated until its vapour has a force of two or even three atmospheres, if the tube be strong enough, and be retained there for a quarter of an hour, or more, without any loss. The portion of common air in the tube is to be allowed to escape or not, according to circumstances (919), and may be made use of at times, as will be found by practice, to prevent the accession of heat to the fingers.

101. Returning to the fluid with which the bulb has been filled :—upon removing the latter when cold, allow its exterior to drain as much as possible ; the wire must then be taken off, the surface wiped, and the bulb put upon a cork stand (67), and weighed. As the vessel will then be required full of water, it must be emptied of the fluid. For this purpose replace the wire handle, invert the bulb, holding its aperture within the mouth of the tube to which its contents are to be restored, and apply a little heat : a part of the liquid will be forced out, or indeed the whole if it be volatile ; if not, on cooling, a bubble of air will enter, and a second and third application of heat will displace the whole of the contents. On introducing a portion of water and displacing it, and repeating this two or three times, the bulb will be sufficiently cleansed ; it may then be filled entirely with water, and weighed when cold as before. The weights of equal bulks of the fluid and water are now known, and the specific gravity readily obtained by calculation.

102. Although the process has been described in this order, it is generally better, after weighing the bulb, to introduce the water and obtain its weight first, and then that of the peculiar fluid; for if an accident happens in the water experiment, and the bulb is destroyed, it does not involve a repetition of the process with the valuable liquid. Further, it is easy at all times to free the bulb from the water of the first part of the process, but not always so to dissipate the remains of peculiar substances which may be decomposable by heat or not soluble in water. The bulb may be emptied of water by first throwing out the larger part as already described, then heating it over the flame of a spirit lamp, or in hot air, to convert the rest of the moisture into vapour, and either retaining it there some time, or, if that be inconvenient, allowing it to cool, that the vapour may condense and the air enter. A second application of heat, at the same time that it converts the remaining water into steam, throws out a portion with the expelled air; being cooled and again heated a few times, the bulb is soon effectually dried. The process may be expedited by cooling a part near the mouth first, which is easily done by touching it with a cold substance (1356), and causing the principal condensation of moisture there, and then also heating the same part first; in this way the air carries out the water in fewer operations, but these facilities are only to be learned and appreciated by practice. In all exposures of the bulb to heat, in experiments relating to specific gravity, especial care must be taken that the heat is not such as to soften the glass after one of the fluids has been weighed; for in that case the form and size of the vessel will be altered, the process must be recommenced, and the previous trouble will be utterly useless.

103. The specific gravity of fluids is frequently ascertained by the hydrometer, a well-known instrument, which is of great service where hasty estimates of only moderate accuracy are required; but it will not give correct or even uniformly incorrect results without attention. The stem being the part which cuts the surface of the liquid, resem-



bles in that respect the suspending link used in taking the specific gravity of solids (87, &c.), and is liable to be affected in a similar way, but in many cases to a much greater extent, because of its necessary thickness. If its surface does not moisten freely with the fluid in which it floats, it will be found easy, upon trial, to make the hydrometer stand two or three degrees, or more, higher or lower in the same liquid; and when the hydrometer does readily become wetted, and has even had the stem purposely moistened, the same effect may be produced, and that not in fluids particularly viscid, but in water and aqueous solutions:—hence a source of irregularity in the indications of the instrument, which must be avoided as much as possible. For this purpose, keep the hydrometer perfectly clean, and free from any unctuous or greasy matter which might be the consequence of handling it. When put into the fluid it should be allowed to sink gradually till at rest, and then be depressed about an inch lower, which will give it an ascending power, and moisten a certain portion of the stem: the jar containing the fluid is to be tapped to cause vibration, and the instrument allowed again to take a state of rest, when its position should be observed. The instrument should then be raised about half an inch out of the fluid, and, tapping the jar as before, suffered to sink slowly, and observed whether it takes the same position it occupied at first: if it does, the observation is as correct in this respect as it can be.

104. If the fluid be viscid, the liability to inaccuracy in this instrument is increased, both by the difficulty with which it sinks or rises to the point to which its mere weight would carry it, and also by the greater quantity which adheres to the part of the stem that, having been immersed, is afterwards raised above the surface. If the fluid be turbid, it is not the gravity of the suspending fluid itself that is obtained, but of the liquid so laden with other matter. Some precipitates will be days, and even weeks, before they will settle from the fluid in which they are formed, and yet are so heavy as very materially to increase the specific

gravity of the whole. Brewers and other persons frequently require the specific gravity of a mixture of solid and fluid matter—their object being, by the buoyance of the hydrometer, to estimate the former as well as the latter, their instruments should be graduated by experiment with fluids similar to those they wish afterwards to examine.

105. In all experiments made with the hydrometer, an ascent of the fluid will take place round the stem, producing the elevation before mentioned (87). This occasions a curve in the surface, and some persons read off the graduation on the stem, where it coincides with the middle of this curve—others at the top, and others again at the bottom. It is necessary, for the sake of consistent observations, always to read off from the same part of the curve; and if the instrument has been graduated by experiment, the divisions being made with reference to the part of the curve from which they are afterwards to be read, it will so far be correct. As the force which causes the elevation tends to depress the instrument in the fluid, observations made at the bottom of the curve will be nearer to the truth than those made at the top. But the curve itself varies, not merely in size, because of differences in the weight or specific gravity of the fluid, but in weight also, because of differences in the cohesive attraction of different fluids.

106. Amongst other points relative to the state of the fluid, temperature should not be forgotten; constancy in this respect being as important as in experiments made with the bottle (93—95).

107. The hydrometer, when first procured, should be verified by trial in solutions of which the specific gravity has been ascertained by the bottle. It is not necessary to make many trials of this kind, its verification being more readily effected in the following manner. First, ascertain with two fluids of different specific gravities, that one indication towards each end of the scale is correct. Then, suspending the hydrometer from the pan on one side of a balance, let it descend into a solution as light, or lighter than any to be measured on the scale, but buoying it up by weights in the other pan, so that the surface of the fluids

shall cut the scale at the lower part. Make equal additions of weight in succession to the pan from which the hydrometer is suspended, and observe the descent each time: if they are equal, as read off on the scale, then the divisions are equal in bulk, and the graduation is correct; if unequal, the graduation is incorrect, and would not correspond with the results obtained by the specific gravity bottle. The more numerous the points thus observed, that is, the smaller the weight added each time, the more accurate and close is the trial.*

108. A solid glass ball, or bulbs of glass, are frequently used for ascertaining the specific gravity of fluids. If a ball of glass suspended from the balance be wholly immersed in a liquid, it will be buoyed up by a force equal to the weight of the liquid it displaces, and seem to lose weight to that amount. By being immersed, therefore, in succession into different liquids, the weights of equal volumes are thus obtained, for the ball measures out the volume each time, and the specific gravities are then known. The precautions here required are the same as those belonging to the experiments on the specific gravity of solid bodies. (81—88.)

109. Sometimes several hollow bulbs of different specific gravities are used; those which are too heavy sinking, and those which are too light floating. The proper strength of some solutions evaporated in the large way is thus estimated. Sea-water, for instance, in salt-works, is concentrated by exposure to air, until it has such a specific gravity, that, of two previously-arranged glass bulbs, one will sink and the other swim. Their use in chemical research is rare; but an excellent instance of the delicacy with which the principle may in some cases be applied, as also a specimen of useful manipulation, may be found in Mr. Crichton's paper on the maximum density of water†.

110. Another instance of the application of similar bulbs to the determination of specific gravity, when no other means were available, occurs with respect to the liquids

* See Moore on the Graduation of the Hydrometer; Dublin Philosophical Journal.

† Annals of Philosophy, New Series, v. 401.

produced by the condensation of gases*. The bulbs used were very small, and made as hereafter to be described (1198). Their specific gravities were ascertained by putting them into different solutions of known specific gravity, and the bulbs thus prepared were introduced into the vessels in which the gases were to be liberated or condensed. When surrounded by the fluid, its density was in some degree judged of by the sinking or swimming of the included bulb, and then, by successive trials with heavier or lighter bulbs, more accurately ascertained.

111. Substitutes for a balance, though not often required, are, in particular situations, very valuable, and there are few philosophic travellers who have not felt this want. Mr. Bevan recommends for this purpose a strung bow †, which, if not at hand, may generally be made out of a piece of whalebone, a stick, or other substance, and which, being suspended by the middle of the bow, is to have the body to be weighed attached to the middle of the string. The flexure occasioned by it is to be observed, which will best be done by marking the point to which that part of the string from which the body hangs, descends: then removing the substance and replacing it by weights, sufficient are to be used to cause the same flexure, and thus the weight of the substance will be obtained. An elastic beam, stick, or other body, firmly fixed at one end, and loaded at the other with the substance and the weights in succession, will answer the same purpose; and the means of making a temporary scale-pan, to receive the substance and the weights, and a graduation to measure its descent, are so simple and evident as not to require description.

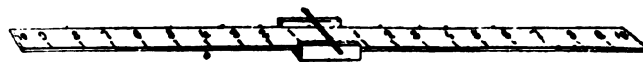
112. The following account of a very delicate and easily constructed balance is from a letter written by Dr. Black to Mr. Smithson‡, and is a valuable piece of information to those who, having occasion for, are deprived of the use of, a good balance. 'The apparatus I use for weighing small globules of metal, or the like, is as follows: a thin piece of

* Philosophical Transactions, 1823, p. 191.

† Technical Repository, vi. 196.

‡ Annals of Philosophy, New Series, x. 52.

fir-wood, not thicker than a shilling, and a foot long, 0.3 of an inch broad in the middle, and 0.15 of an inch at each end, is divided by transverse lines into 20 parts, that is, 10 parts on each side of the middle. These are the principal divisions, and each of them is subdivided into halves and quarters. Across the middle is fixed one of the smallest needles I could procure, to serve as an axis, and it is fitted in its place by means of a little sealing-wax. The numeration of the divisions is from the middle to each end of the beam. The fulcrum is a bit of brass plate, the middle of which lies flat on my table when I use the balance, and the two ends are bent up to a right angle so as to stand upright. These two ends are ground at the same time on a flat hone, that the extreme surfaces of them may be in the same plane; and their distance is such that the needle, when laid across them, rests on them at a small distance from the sides of the beam. They rise above the surface of the table only $1\frac{1}{4}$ or 2 tenths of an inch, so that the beam



is very limited in its play. The weights I use are one globule of gold which weighs one grain, and two or three others which weigh one-tenth of a grain each; and also a number of small rings of fine brass wire, made in the manner first mentioned by Mr. Lewis, by appending a weight to the wire, and coiling it with the tension of that weight round a thicker brass wire in a close spiral, after which the extremity of the spiral being tied hard with waxed thread, I put the covered wire in a vice, and applying a sharp knife, which is struck with a hammer, I cut through a great number of the coils at one stroke, and find them as exactly equal to one another as can be desired. Those I use happen to be the one-thirtieth part of a grain each, or 300 of them weigh 10 grains, but I have others much lighter.

'You will perceive that, by means of these weights placed on different parts of the beam, I can learn the weight of any little mass, from one grain or a little more to the $\frac{1}{1000}$ of a grain. For if the thing to be weighed weighs

one grain, it will, when placed on one extremity of the beam, counterpoise the large gold weight at the other extremity;—if it weigh half a grain, it will counterpoise the heavy gold weight placed at 5;—if it weigh 0.6 of a grain, you must place the heavy gold weight at 5, and one of the lighter ones at the extremity to counterpoise it; and if it weighs only one, or two, or three, or four hundredths of a grain, it will be counterpoised by one of the small gold weights placed at the first, or second, or third, or fourth division;—if, on the contrary, it weigh one grain and a fraction, it will be counterpoised by the heavy gold weight at the extremity, and one or more of the lighter ones placed on some other part of the beam.

‘This beam has served me hitherto for every purpose; but had I occasion for a more delicate one, I could make it easily by taking a much thinner and lighter slip of wood, and grinding the needle to give it an edge. It would also be easy to make it carry small scales of paper for particular purposes; the fulcrum being then placed on a stool or any other support that is horizontal, raised and narrow.’

113. Dr. Ritchie also contrived a very cheap and delicate balance. It consists of a slender beam of wood, about 18 or 24 inches long, tapering a little from the middle to each end. A fulcrum of tempered steel, resembling the blade of a penknife, is made to pass through the middle of the beam a little above the centre of gravity. Similar steel blades are also made to pass through the ends of the beam for suspending the scales. The fulcrum rests on two small portions of thermometer tube, fixed horizontally on an upright wooden support, held firmly by a foot; the support has a slit passing along the middle, to allow the indicating needle attached to the beam, beneath the centre of gravity, to play freely between the sides. A small scale made of card, and divided into any number of equal parts, is placed on the support for the purpose of ascertaining the point at which the needle becomes stationary. This balance, Dr. Ritchie says, possesses extreme delicacy, and may be made even more sensible than that belonging to the Royal Society of London.

114. The equality of the two ends is not a necessary consideration, according to the method of double weighing referred to before, and invented by Borda. To weigh with the balance, let the body be placed in one of the scales, and bring the indicating needle to any point by small shot placed in the other scale; remove the body and replace it by as many known weights as will bring the needle to the former position. These weights give the weight of the body*.

115. In weighing with these balances, or generally with such as are a little out of order, the weights should be applied and ascertained on the same side with the substance, that irregularities of action may be avoided as much as possible. Thus, the substance to be weighed should be put into one pan and counterpoised by any convenient thing, as sand, in the other; after which, removing the substance, its place is to be supplied by weights, until an exactly equal effect is produced, when of course the amount of the weights used will be the weight of the substance. Or if a given quantity be wanted, first counterpoise the weight and afterwards replace it by the substance to be weighed. Inequality in the arms is thus compensated.

116. Substitutes for weights, should they ever be required, may be made by means of a balance in one or two ways. Pieces of metal or other convenient substances may be adjusted to have equal, double, triple, or any other proportion of weight, to a standard piece, and, being used as weights at the time, will give proportionate results; or if results comparable with other weights are required, their value may be estimated by actual comparison at a future convenient opportunity. Such regular weights, of considerable accuracy, are easily obtained by cutting off equal or given lengths of a copper wire, the wire being of such thickness that at least half an inch in length may be allowed for the smallest weight: its uniform thickness should be ascertained by trying the first and the last weight cut off against each other. Occasionally the products obtained from experiments may be balanced by pieces of lead, which

* Brewster's Journal, v. 118.

are to be weighed when an opportunity occurs, and the results numerically estimated.

117. A method of making small weights has been already described in Dr. Black's letter (112), but Mr. Smithson finds it preferable, first to ascertain the weight of a certain length of wire, and then to take that portion of it which may suffice for the weight wanted. If fine wire is employed, a set of small weights may be thus made with great accuracy and ease. Inconvenience from the length of the wire in the higher weights is obviated by rolling it round a cylindrical body into a ring, and twisting this to a cord.*

118. The following relative table of different weights will be frequently used in the laboratory.

	Grains.
Pound avoirdupoise	7000
Ounce avoirdupoise	437.5
Pound troy	5760
Ounce troy	480
Gramme	15.4063
Decigramme	1.5406
Centigramme	0.1540
Milligramme	0.0154

SECTION III.

MEASURES—MEASURING.

119. ORDINARY laboratory service requires no other measures than such as are fitted to ascertain the bulk of liquids or gases. Hence two integers are abundantly sufficient, the pint and the cubic inch. The pint measures may be such as are furnished in commerce, either conical, cylindrical, or of any other form, and of glass, and graduated: but they should always be verified before they are permitted to pass into use. Where the same measure is used for large as well as small quantities, those which are conical have an advantage in the smaller divisions over such as are cylindrical, the surfaces of small quantities being less, and consequently the bulks more accurately determined; but

* *Annals of Philosophy*, New Series, x. 53.

it is better to have two or three measures of different sizes, varying in diameter, for different quantities. The wine pint measure has been usually divided into sixteen parts, each being called a fluid ounce, and liquids were frequently measured by these ounce volumes, which in such bulk weighed more or less than an ounce. The standard or imperial pint now to be used is larger than the wine pint, in the ratio of 6 : 5 (154). It is to be divided into twenty parts, to be called fluid ounces: these will not be the same exactly with the former fluid ounces, but will have the great advantage, when estimated with distilled water, of *weighing* an exact ounce avoirdupoise. The measure should be graduated in two places on opposite sides, that when the vo-



lume of a fluid is to be determined, its surface may, for greater accuracy, be observed by both graduations. A pint, a half pint, and a quarter pint measure, of the form and relative dimensions as to height and diameter of the one figured in the wood-cut, should be in the laboratory. It is also useful to have a graduation on the vessels in cubic inches, this being done on both sides at equal distances from the former graduations.

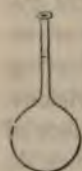
120. These measures should be graduated according to the last parliamentary standard, by which the pint is ascertained to consist of 8750 grains of water at 62° Fahrenheit, barometer at 30 inches; and the cubic inch of 252.458 grains of water, at the same temperature and pressure. They are verified by being counterpoised (64), and having these quantities of water, or their multiples, or divisions, weighed into them, and the coincidence of the surface of the liquid and its corresponding mark noted. If they do not agree, a slight scratch should be made with a diamond or file, at the place where the mark ought to be (132).

121. Preparatory to the use of these vessels, one particular place upon a table or shelf should be selected, which is flat, firm, and should generally be kept clear of other things for this purpose alone. The measure, when placed upon it, should stand steady and perfectly upright. In the verification, it will be necessary to observe, that when the

measure containing the weighed quantity of water is placed in this situation, the surface of the fluid should coincide both with the graduation on the near, and also on the farther side: this is best seen by bringing the eye to a level with the surface; and still further security is gained as to the right position of the measure, if the water stand at equal heights on the lateral graduations of the denomination not immediately in use. In measuring at any future time similar precautions should be observed, and these will require attention the more imperatively, if from any circumstance one particular spot is not selected, as above advised, but, on the contrary, any part of the table used.

122. With liquids which moisten the glass, an elevation of the fluid round its surface in contact with the vessel will take place. The measurement, except in minute vessels, will be most accurately made, if taken from the general surface of the fluid, and not from the middle or top of the elevation (769); but it is essentially necessary that it be always made in the same way as that adopted in the verification of the measures. With mercury there will be a depression round the glass instead of an elevation, except in particular circumstances. It is here again most correct to make the estimate from the general surface of the fluid.

123. When very accurate measurement is desirable, as in the analysis of a mineral water, it is better to perform it in a globular vessel having a glass neck, and of such capacity as to be filled partly up the neck by a weighed pint or half pint of water at 62° ; the exact place being then marked with a diamond or file. So little surface is left at the place where the bulk is estimated, that scarcely any variation can occur in that respect; and if the measurements be made at a constant temperature, they are very accurate. Two such measures, a pint and a half pint, will be sufficient. Small quantities are generally more accurately determined by weight than by measure.

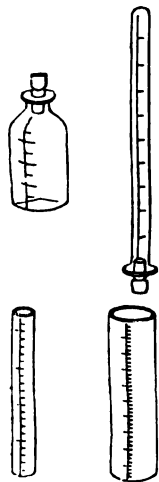


Three jugs, of half a pint, a pint, and a quart, will be found of great service for ordinary use.

124. The cubic inch, with its divisions and multiples, is

used both for liquids and gases. For exclusive liquid use, the cubic inch graduation on the vessels already mentioned will suffice; those to be described will serve generally for both forms of matter.

125. Bottles are sold by the instrument-makers, which contain an exact cubic inch when the stopper is put into its place. Tubes also of similar capacity, and supplied with a ground stopper, are manufactured with a graduation on the side, by which the subdivision is carried to tenths and twentieths, and even farther if necessary. Whether these are in the laboratory or not, there should be, at all events, a few jars and tubes accurately graduated into cubic inches, tenths, and hundredths; one jar may be about two inches in diameter and six inches high; another about an inch in diameter, and of the same height; a third, which will be almost a tube, half an inch in diameter, and eight or nine inches long; and a fourth of the same length,



but still smaller. These should be moderately thick, so as, when filled with mercury, to bear the weight of that metal, and sustain laboratory use without great risk of breaking: they should be ground at the ends, so as to be closed accurately by a flat piece of glass (1348). It will be sufficient that the smaller vessels be graduated on one side only, but it is better that, when the diameter is an inch and a half or more, they should be graduated on opposite sides, for the purpose of observing more accurately, as before explained (121).

126. All these measures should be verified by weighing into them successive portions of water or mercury. A cubic inch of water at 62° weighs, as before mentioned, 252.458 grains, and a cubic inch of mercury at the same temperature 3425.35 grains.* Water is very convenient for the estimation down to the cubic inch, and some divi-

* This assumes the specific gravity of mercury as 13.568, which is what I find pure mercury to possess at 62° Fahrenheit. Sir H. Davy makes it heavier. Of

sions below it; but for the tenths, and especially the hundredths, mercury is far more exact and expeditious.

127. It is frequently necessary to graduate vessels, and especially tubes, in the laboratory. The general method of doing this will be easily understood from what has been said with regard to the verification of measures bought of the maker; but there are some facilities in the practice which will require description. Tubes are generally in use for the measurement of gas at the mercurial trough, and should be several in number, and of different diameters, to afford opportunity for a graduation more or less minute. The laboratory is but poorly stocked that has not a dozen of them. They should not be less than the one-fifteenth of an inch in thickness when of a diameter smaller than half an inch, and thicker if wider. The closed ends should be of equal thickness with the sides, and should be round, not pointed.

128. The marks on vessels graduated by the instrument-maker are cut by the glass-grinder's wheel, but in the laboratory they are made with simpler instruments. A gun-flint is convenient for scratching on the surface of glass. Fragments of diamond are also set in handles for the same purpose; they are not intended to cut, but merely to abrade or roughen the surface, and are called scratching or writing diamonds (974). Small three-square files, about half an inch wide on each side, are so useful in the laboratory for marking on convex surfaces of glass or for cutting tubes (1152), that they cannot be dispensed with.

129. Having selected the tube, first draw a line upon it from top to bottom. This is easily done by laying the tube upon the table, against the edge of a flat slip of wood or a ruler, and drawing either the flint or scratching diamond down it where it rests against the ruler, bearing as it were into the angle formed by the ruler and the surface of the tube. The line should not be broad and rough, but regular, neat, and straight. The tube is now to be balanced by a counterpoise (64), and is then ready to receive the suc-

course any metal likely to enter as impurity into mercury would render it lighter.

cessive portions of mercury, by which equal given volumes are to be measured out, and to have them marked off by small lines across the long one first drawn. Suppose the hundredths of a cubical inch are to be marked down, the tube being about 2-10ths of an inch internal diameter: 34.25 grains of mercury, which at 62° Fahrenheit are equal in bulk to the one-hundredth of a cubical inch, are to be weighed into it; the tube is to be marked at the level of the mercury, another 34.25 grains of metal is to be weighed in, and its place marked on the scale, and the operation so carried on until the graduation is finished.

130. But easy as this is in description, it is otherwise in practice, without the aid of certain facilities. If the mercury be added without care, either too much or too little will be introduced; and when the adjustment is nearly complete, scarcely little enough can be given or taken away, owing to the density and cohesion of the metal. Prepare, therefore, a tube like the one represented in the drawing (1180), about half an inch in diameter, four inches long, cut level at one end, so as to be closed by



the finger if required, and drawn off laterally to a capillary opening at the other. If mercury be poured into such a tube, it will not flow out at the capillary opening whilst the position is such as in the figure, and this is easily given to it on the table by resting it on a list ring (68). But when elevated sufficiently, the pressure of the column of metal will cause it to flow out, and either in a continuous stream or in minute successive drops, according to the degree of inclination: a still greater command over the flow of metal is obtained by applying the finger to the upper extremity and thus relieving the metal from the pressure of the atmosphere upon its upper surface to a greater or smaller degree, as may be required. It is easy in this way to supply more or less of the metal at pleasure.

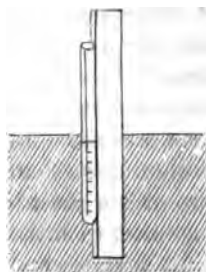
131. When therefore 34.25 grains of mercury are wanted in the tube, place the latter in one pan, and weight amounting to 34.25 grains in the other; then, introducing the capillary extremity of the mercury feeding-tube into the

mouth of the balanced tube, allow metal to flow in, moderating its addition as the balance approaches equilibrium, ultimately adding it only in minute drops. In this way the weight required is nearly attained in a very short time. Have it rather a little over than under weight, and, relinquishing the feeding vessel, proceed to adjust the portion in the tube to be graduated. For this purpose, close its aperture with the fore-finger of the right hand, invert the tube and its contents, which will of course cause the mercury to rest partly on the finger, and then by slightly relaxing the finger, let a little drop squeeze out beneath the edge of the glass into the palm of the left hand, where it is to be preserved. Restore the tube to its right position, and place it in the balance; if too heavy put the first drop of mercury out of the hand as useless, and take a second drop from the tube as before. In this way it will ultimately be obtained too light, but only by a part of the minute drop in the hand. Break this drop into several spherules by pressing upon it with the finger, and take one, two, three, or more of them into the tube, by pressing the edge of the glass against the palm just beneath the drops, when they will roll in; observing each time whether the mercury in the tube balances the weight. In this way accurate adjustment may be obtained in a portion of time not exceeding a fourth part of that required to read this description.

132. The next object is to mark the volume occupied by the mercury, that being exactly the one-hundredth of a cubical inch. The mark will be best made with a three-square or flat file; and it will be found much easier to commence it from the cross line running up and down the tube, than from an unbroken surface. To make a fair mark requires a steady pressure on the file, and then motion to a slight extent. The feel will indicate whether a mark has been made, but the learner should practise first on a piece of waste glass tube, commencing both from an unabraded surface and from a cross line; and by making a mere spot, or marking a line of half an inch in length. He will in this way learn in half an hour to appreciate, by the feel, the kind and the extent of mark he makes. He should also prac-

tise marking upon any desired spot. For this purpose the tube should be held in the left hand, with the thumb close upon the spot to be marked; then placing the edge of the file upon the particular place, and supporting the pressure at the same time by the thumb at its side, the slightest possible motion, sufficient to break the surface, should be given. If the commencement be exactly in the right place, there is no difficulty in continuing it, the file, when its motion is renewed, catching the previously roughened part; if the commencement be in the wrong place, another trial must be made: the practice of making the mark where desired will soon be acquired.

133. This point attained, the next thing to be done is to mark the tube so as to record permanently the volume occupied by the mercury. For this purpose it must be placed in a steady upright position; and though this may be effected sufficiently well with very small tubes by holding them firmly in the hand, yet it is an incorrect method with larger ones. Choose therefore a flat place on the wall, in a convenient situation, and at the height of the eye. From a line level with the eye, and about two or three



inches downward, and for a width of five or six inches, blacken the wall, either by pigment or attaching a piece of black paper to it. Then firmly fix a piece of wood planed smooth and true, about the third of an inch thick, an inch wide, and six inches in length, to the wall in an upright position, across the middle of the blackened part, so that half its length shall be on the white part above. Two upright re-entering angles are in this way produced, against which the tubes may be firmly held, and the necessary position thus effectually obtained. The black and white surfaces behind will each be found advantageous in turn, for showing the coincidence of the surface of the mercury with any particular part of the glass, according to the light and other circumstances; and by shifting the tube a little up or down, the part where the mercury stands

may be placed on one or the other at pleasure, and yet the eye be brought to the same horizontal line with it without any difficulty. By this means the position of the tube, of whatever size it may be less than an inch, is securely obtained, use being made of the angle on either side of the lath. An advantage sometimes results from using a piece of lath planed obliquely, so as to be thicker at one edge than the other; large tubes being applied to the deep angle on one side, and small tubes to the shallower angle on the other. Sometimes an angle previously existing on the walls of the laboratory, as that formed by a bead, may be used for these purposes.

134. The tube when held in the angle may easily be marked, as before mentioned, by laying the three-square file horizontally across it upon the perpendicular line previously drawn, and abrading the surface by a little motion and pressure. The first mark is merely to be a slight extension of the rough surface on the side of the line; a mere spot, which, if wrong, may be neglected, and another made; if right, may afterwards be lengthened into a line. There is no necessity for retaining the tube against the wall whilst the division is being fully marked; if the commencement be correct, the tube may be taken down, and the line completed in any other position that may be convenient.

135. But there is yet another point to be considered before we can proceed thus far. Mercury, when contained in glass vessels, is, in consequence of its cohesive attraction, depressed at that part of its surface where it verges towards the sides of the vessel; the place of contact with the glass is thus rendered lower than the general surface, and consequently a small space beneath that level remains unfilled by the metal. Hence a mark made to correspond with that surface would include a space in the vessel rather larger than that occupied by the metal; and though in wide vessels or tubes the error thus introduced is minute, it is not so in tubes of small diameter, and frequently amounts to one of the divisions marked upon them. When to this is added the consideration that the convexity of the mercury, in graduating a tube, is the reverse of that which occurs

when using the same tube over mercury to measure gas (798), it is evident that always reading off from the top or bottom of the curve would but increase the errors in this case; and that with small quantities of gas, and in delicate experiments, they would become very serious. To these may be added another circumstance, which complicates the errors still further, namely, that when the tubes are used with or over water, the convexity is the reverse of that with mercury, and the correction required consequently of a contrary kind.

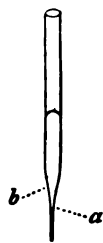
136. With reference to the process of graduation, the difficulty thus introduced may be avoided by using mercury which is not quite clean, but which, from containing a little of some other metal, as tin, lead, &c., has a film formed upon its surface. The mercury of the pneumatic trough, if in much use, is generally of this kind, or a small quantity can be readily made so for the purpose, by adding one grain of lead to four or five thousand grains of the fluid metal, that quantity being quite sufficient. When such mercury is put into a tube, a slight tremor given to it extends the film and allows the metal to flow beneath, so as to acquire a flat surface instead of a round one, and then the volume may be accurately marked off by a line upon the glass coinciding with that surface (138). Care is to be taken that the mercury used be not excessively foul, or so dirty as to throw up a thick coat of film to its surface, since no indication of volume belonging to a given weight of mercury would then be obtained.

137. No further difficulty will now arise in the way of graduating a tube. The 34.25 grains of mercury are to be weighed in, the tube is to be placed against the wall, slightly shaken to produce a level surface, and then a division is to be marked by the file. Another 34.25 grains of mercury are to be weighed into the tube to the metal already contained in it, and the volume is to be marked as before; third, fourth, and fifth divisions are to be obtained in the same way, and thus a scale will be gradually produced.

138. By degrees the tube, if large, will contain so much mercury as to be too heavy for the balance. But it is then

easy to use a smaller vessel to weigh the metal in, transferring the mercury from that into the tube each time, and graduating as before. One advantage of thus weighing the measuring portions of metal in a separate vessel is, that water may be introduced into the tube under graduation. This facilitates the production of the level surface required on the mercury, and sometimes assists in marking down the graduations, by the particular appearance of the tube: but as dirty mercury froths more readily in water than in air, the operator should be aware of any error in bulk that might arise from this cause; and a little time should also be allowed before a mark is made, that the water may pass to the surface from between the glass and the metal, and the mercury attain its level. No quantity of water that is worth consideration will remain adhering to the glass after it has stood a few seconds.

139. There is another mode of obtaining the successive portions of mercury; it is by measuring instead of weighing, yet with such accuracy as to be unobjectionable, and is as follows. Procure a piece of glass tube, of such diameter that the division required shall occupy in it from half an inch to an inch in length; for hundredths it may be one-sixth of an inch internal diameter, and for tenths, about



one-third of an inch; draw out one extremity at the lamp table, so as to give it the form in the figure (1180), the lower end being a capillary continuation, from which mercury will flow out in a small stream, by the pressure of half an inch of metal above. Close the lower extremity by introducing the tip into the flame of a spirit lamp, so that the sealed part may afterwards be cut off without removing more than the one-sixteenth or one-eighth of an inch. Counterpoise the tube. Now weigh into it (if for hundredths) 34.25 grains of mercury, or if for tenths, 342.53 grains; and when the weight is accurately adjusted, observe whether the metal be continuous throughout; if not, make it so. The only thing which will interfere with this continuity is the occurrence of a bubble or two of air about *b* (see the figure). These are easily removed by

introducing a horsehair or thin platinum wire down between the glass and the mercury, until it reaches the bubble, the air of which will immediately pass up by the hair or wire. The air which is sure to remain in the capillary part may be removed in the same manner as low as a , but it is better that a small but constant portion should remain between the bottom of the mercury and the sealed part. The next thing to be done is to mark the tube at the surface of the mercury, and by weighing in two, three, four, or more portions, each of 34.25 grains, and marking off their heights, an accurate graduation will be produced. Now by the scratching of a file, and then a little lateral force as directed in glass-blowing (1152), cut off the sealed capillary end about half way below a , and thus open that extremity.

140. The measure is now complete, and all that is further requisite is the mode of using it. Suppose mercury, equal to one or more divisions, were required; pour some of the metal into the measure above its highest division, at the same time closing its capillary opening by bearing a finger slightly against it; then shutting the top by the fore-finger, allow the mercury to run out at the capillary termination (130), until its upper surface coincides with the uppermost line. Now stop the stream by inclining the measure; until, having directed the jet into the tube to be graduated, any mercury that afterward passes out may be received by it. Again relieve the finger above, so that the metal may fall as before, passing through the extremity into the lower tube; and when the level in the *measure* again coincides with a division, it will be known that the hundredth of a cubic inch has gone from it into the tube to be graduated. Prevent the passage of more mercury by inclining the measure; mark off the portion already transferred; then add a second hundredth in the same way, and proceed in this manner to any extent required. When once a measure of this kind is made, it is exceedingly convenient and ready in its use, and, being of sufficient length, will readily serve to estimate tenths as well as hundredths.

141. One other mode of measuring the mercury in these

cases of graduation it will be necessary to mention, because it is common, and at times has peculiar advantages. It consists in forming a tube which, when closed with the finger, shall hold exactly the quantity of mercury required. The use of such a tube requires a little practice, for when the diameter is more than the third of an inch, variations in the pressure of the finger upon its open end, or the use of the finger or thumb indifferently, cause sensible variations in the quantity contained. By practice such uniformity is obtained, however, as not to involve any important error.

142. These measures are best made in the following manner: select a piece of tube sealed at one end, with a rounded termination, and which shall be competent to hold about twice the bulk desired; counterpoise it, and then weigh in the mercury corresponding to the volume required. Mark this volume, and, pouring the mercury into another tube or dish, cut off the measure (1152) as near as may be to the mark; leaving it, if not exact, rather larger than is required. Draw out a few thick threads of cement (1123, 1125), or make a thin roll of wax, and, having poured the mercury back into the intended measure, put upon it a piece or two of the cement or wax, and, covering it with the finger, depress it into the fluid metal, and observe whether there be sufficient to fill the tube or not: the wax or cement is to be increased or diminished in bulk, until with the mercury it exactly fills the tube when closed by the finger; and this adjustment is to be made over a Wedgwood basin, that any particles of mercury thrown out during the trial may be readily returned to the tube, and prevent alteration of the original quantity. When this adjustment of the wax has been obtained, pour out the mercury, drop the wax to the bottom of the tube, warm the latter so as to melt the wax, and then allowing it to cool, the measure is completed; but for greater security, verify it by ascertaining that it does measure out the right weight of mercury.

143. It is not necessary in every case to weigh out mercury for each division on the graduation; for when the di-

visions are small, as on a comparatively large tube, it can frequently be effected as accurately, or more so, by the unassisted eye, as by measurement with mercury. Thus, for instance, if a tube of one-fourth of an inch in diameter were to be graduated into tenths and hundredths of a cubical inch, and, by measuring every four hundredths by some of the preceding methods, the resulting divisions were found to be as nearly as possible equal in length, and consequently the tube uniform, then the single hundredths may, by very little practice, be marked off by the eye alone more accurately than by any other method usually adopted in the laboratory, and sufficiently so for the most refined experiments. The object is of course to divide the space of four hundredths, first into two of two hundredths, and each of these into two of one hundredth. This is best done, not by holding the tube vertically against the wall, but laying it horizontally upon the table on a surface of uniform colour; and the division should first be made by dots as before mentioned (132), and their uniform and accurate distance acknowledged by the eye before the lines which are to form the scale are marked. Very little experience will show the value and rapidity of this method, which, in the hands of a careful person, may be extended to the division of a space into 5, 6, 8, 10, or even more parts.

144. Where the mercury is *measured* into the tube to be graduated, every five or ten portions put in should be transferred to the balance and weighed, to ascertain their correct accordance with the quantity marked on the graduation. Thus, supposing the measuring tube before described (139) to be in use, when twenty divisions have been transferred from it the operator should ascertain that the mercury in the tube to be graduated actually amounts to twenty times 34.25 grains, and, when forty divisions have been put in, that 1370 grains of mercury are there.

All these experiments relative to the weighing and measuring of mercury should be made on a tray, or over the mercury-table (12).

145. In marking the divisions every fifth and tenth should be distinguished from the others, for the purpose of

ready observation; the fifths by a little extra length, and the tenths by being marked on both sides the upright line, as indicating larger divisions.

146. In eudiometrical and other experiments with small quantities of gas, very small divisions are required, and sometimes other parts than those of the tenths or hundredths of a cubical inch are, from their size, useful. In these cases it is far better to take other subdivisions of the cubical inch than to have an independent standard, and through it introduce complexity into the laboratory measures. If hundredths are not small enough, divide them into two hundredths, or five hundredths, or thousandths; or if hundredths are too small, count two of them as one part, which may easily be done upon the tubes graduated as already described; and indeed every other division may be distinguished by a little additional mark opposite to it on the other side of the perpendicular line.

147. In graduating tubes for eudiometry or any other purpose, Dr. Henry has long been in the habit of using a contrivance which renders the operation very quick, and insures perfect accuracy. It consists of a tube open at both ends, and not more than 0.08 of an inch in diameter. This is carefully divided into equal parts, which may be entirely arbitrary, but those which he employed are ten grains of mercury, at 60° Fahrenheit, the whole tube containing 100 grains. It is some trouble to divide this tube, but when once prepared any number may by its means be easily graduated. The successive portions of mercury used in dividing wider tubes are measured by this, into which they are drawn, either by plunging it into a jar filled to sufficient height with that fluid, or by the action of the mouth.*

148. The graduation of jars is to be effected in a manner very similar to that which has been recommended for tubes; but if performed by weighing, water is a better substance than mercury for all quantities above half a cubic inch, because of the weight of the latter, and the consequent burden it occasions to the balance. A cubic inch of water at 62°, it will be remembered, weighs 252.458 grains.

* Manchester Memoirs, Second Series, vol. ii.

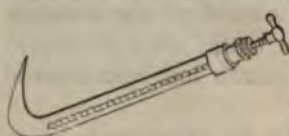
If measures are to be used, the vessels for them should be perfectly clean, so as to become wetted over the interior : they should be well rinsed out with water, and after being left to drain for a few seconds, should, without further drying, be counterbalanced before the given weight of water, which is to form the standard, is introduced, and its volume marked (139, 141) ; because on every occasion for their use a similar quantity of moisture will be left in them, after the liquid by which the graduations are to be made has been poured into the jar.

149. In marking the jars it will not be advisable to place them against the wall, as has been directed for tubes ; their larger diameter interfering with such an arrangement. They should be put upon a steady, firm place, as the one appointed for measuring (121) ; and the liquid having acquired a state of rest, three points should be marked, upon upright and equidistant lines, corresponding accurately with the general surface of the water in the jar. These points are best obtained in the first place by the scratching diamond (128, 974), and may afterwards be extended into short lines by the file (132).

150. When the jars to be graduated are such as cannot stand steadily upon their own bases, the graduation at three different places becomes still more important. Thus with such as are capped, and, being closed with a stop-cock, require, when graduated, to be supported on other jars, or list rings (68), or over holes, the triple graduation is a security independent of a correct perpendicular position. For though the jar might perchance shift a little in its situation from the perpendicular, still if any quantity of water, for instance 20 cubic inches, were then marked off by three lines on different sides of the glass, any quantity which at a future time should coincide with those marks, would be known to be accurately 20 cubic inches. This might be effected, indeed, by two graduations on opposite sides, but it would not be so certain in practice as three. In using three, also, the two first, if minutely incorrect, may be adjusted to perfect accuracy, by very slight motion of the jar before the third mark is made. The necessity of making these graduations

at one temperature, that of 62° , has been before insisted upon.

151. Several instruments have been constructed by Dr. Hare*, in which he has introduced a mode of measuring, dependent upon the displacement of certain volumes of liquids or gases, by the different parts of a graduated rod.



The figure represents one of these instruments. It consists of a glass tube fixed by one extremity into a cap and collar of leather, and terminated at the other in a capillary

opening. A rod graduated into equal parts passes air-tight through the collar of leather, and is moved by a handle at the exterior. If the aperture be immersed in water, and the rod drawn out and thrust in again several times, the air is ejected, water enters, and by inclining the instrument it may be entirely filled with the latter fluid, and left with the greater part of the rod in the air. If it be then removed from the water and dried, it is evident that, by inserting the rod, a volume of water equal to it will be expelled from the tube by the capillary aperture, and may be transferred into the vessels to be graduated; it is also evident that this water may be thrown out in successive minute portions, each equal to the other, and to one of the graduations on the rod. When the whole of the rod is thrust in, it is easy, by drawing it out, to replace it by water, as in the filling of the instrument, and then additional equal bulks of water may be measured out.

152. By terminating the tube as before described (130), and using mercury instead of water, the instrument becomes an excellent measurer of equal portions of mercury, and may then be used in graduating tubes (137). The rod itself is easily graduated to any required dimensions, by observing how much of its length must be inserted to displace a given weight of mercury, as 34.25 grains (137), and then by proceeding to mark off other degrees of equal value.

153. An instrument of this kind may be made without

* Phil. Mag. lxvii. 21.

difficulty, from a tube like that figured at p. 71; the rod may be of solid glass, or a glass tube closed at the inner termination; it should be made to slide through some tow, well impregnated with tallow, which, being wrapped round it, is to form a plug sufficient to close the end of the tube. By tying this over with a piece of cloth, it may be made quite firm and air-tight; and the rod may then be graduated experimentally.

154. The following are useful estimates and comparisons of certain measures, both linear and cubic, with the weights of the cubic measures in grains of distilled water added.

	Inches.
Yard	36
Metre	39.37079
Decimetre	3.93708
Centimetre	0.39370
Millimetre	0.03937

The seconds pendulum vibrating at London, 39,13929 inches.

	Cubic Inches.		Grains of distilled Water.
Imperial gallon . . .	277.274	....	70000
Imperial pint . . .	34.65925	....	8750
Imperial fluid ounce .	1.7329625	....	437.5
The old wine pint . .	28.8827	....	7291.666
Old fluid ounce . . .	1.805169	....	455.73
Cubic inch	1.	....	252.458
Litre	61.02525	....	15406.312
Decilitre	6.10252	....	1540.631
Centilitre	0.61025	....	154.063
Millilitre	0.06102	....	15.406

SECTION IV.

SOURCES AND MANAGEMENT OF HEAT.

155. HEAT is so important, as modifying chemical action, and the chemical and physical properties of bodies, that it must always be of the utmost consequence to the chemist. So great is its influence over his researches, that he has been called the philosopher by fire; and though the consideration

of its peculiar action on matter forms no part of the direct subject of the present volume, yet, as the modes of augmenting and applying it are proportionate in number and extent to the powers of the agent itself, so the sources and management of heat will claim much present attention. It is, however, by no means intended here to dwell upon this subject in its full extent, but rather to limit and compress it as much as possible; supplying to the student that portion of instruction which relates to the simplest and most effectual means of obtaining the temperatures he may require in his experiments, but not extending it to every furnace, lamp, or blow-pipe, beneficially used in chemical arts and processes.

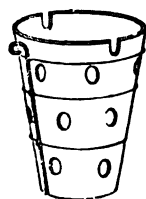
§ 1. *Furnaces.*

156. There is scarcely any limit to the number of furnaces that have been contrived, as particularly adapted either for special or general uses; all no doubt were good at the time they were devised, and superior for some reason or other to those which had preceded them. But the character of chemical operations has changed so much as to render many of these contrivances useless, or of little importance, and each person is now left to select those which are most agreeable to himself, as according best with either his notions or modes of experimenting. For these reasons, the author will here describe those which he has been induced to adopt as economical and effectual; convinced that he ought not to omit them, and that to describe a greater number would be assigning to this subject a larger proportion of the present volume than it can fairly claim.

157. An exceedingly useful furnace, either in a large or small laboratory, may be made out of a black lead or earthen crucible. The proper vessels for this purpose are known by the name of *blue pots*, and may be had of almost every size, less than the height of 22 inches, and of 12 or 14 inches diameter at the top; they are made of clay and plumbago mixed, and are easily cut by a saw, rasp, or file. The price of one, which will make a very good furnace for small operations, is about six shillings.

158. One of these vessels, of the height of 12 inches, and 7 inches in width at the top within, will make a very useful

furnace for the igniting a small crucible, heating a tube, or distilling with large glass retorts at moderate temperatures, or with smaller glass or earthen retorts at higher temperatures. It is in the course of preparation necessary first to have certain round holes pierced in it. These are easily made: a gimlet, brad-awl, or other small instrument, is to



be used, to penetrate the sides, and the small apertures thus produced are to be enlarged with a rat's-tail and round rasp, and ultimately finished with a half-round rasp, which will make them of the size required. Four of these holes are to be placed at equal distances from each other, and about two inches from

the bottom of the pot; they may be $1\frac{1}{4}$ or $1\frac{1}{2}$ inches in diameter; a second ring of holes, five or six in number, is to be made half way between the top and bottom of the pot, and a third row of five or six within two inches of the top; these holes should be rather smaller than the four lower ones.

159. The pot should now be bound round with iron or copper wire, $\frac{1}{8}$ of an inch thick, to strengthen and hold it together when it cracks,—an effect which is sure to take place after it has been a few times heated. The wire should be carried round in three different places, just above the upper holes, between the top and second row, and between the second and lowermost row. A single wire, especially if of iron, is sufficient, and two or three long notches should be made with the edge of a rasp in the line of each ring of wire, just deep enough to receive it and prevent it from slipping down when drawn tight; the ends should then be twisted together. It is very convenient to have a handle to these furnaces, by which they may be lifted, when hot, with a pair of tongs or a hook. It should be of iron wire one-eighth or more of an inch in thickness; one piece should be carried under the pot, and lodged in a groove deep enough to receive it, and prevent unsteadiness; it should rise up on opposite sides of the furnace, until near the top, and there be turned so as to form a hook or ring on each side to receive the handle. This wire should be put on at the same time with that which binds the whole together,

and the latter wires should take a turn round the former wherever they cross it, which will add considerably to the strength of the whole. The handle above is easily made of a piece of the same thick wire curved over the top of the furnace, and bent into hooks at the extremities, by which it is to be attached to the former piece. The handle should have such a curve that when not in use it may pass over the edge and lie out of the way against the side of the furnace, or it may be kept separate.

160. A small round moveable grate of cast iron, like that figured in the wood cut, makes this furnace complete for many operations. If it be required to heat a crucible, the grate should be of such a size as to drop into the furnace, and rest between the bottom and the second row of holes. The part below then forms the ash-pit, to be supplied with air for the fire by the four holes; and the part above forms the body of the furnace to receive the fire and crucible. If a shallow fire only is wanted, as in processes of distillation or the heating of tubes, the grate should be of such a size as, when dropped into the furnace, to descend only a little below the first tier of holes, the ash-pit then having two tier of holes entering it. Half a dozen of these small grates will be required in the laboratory, for the purpose of fitting at different times into different parts of the same furnace, and also for use in different sized furnaces, of the kind now described. They are of small price, and may be bought of the philosophical instrument maker.

161. When furnaces of this sort are constructed of different sizes, variations in the number and arrangement of the air-holes will of course suggest themselves. A smaller furnace will require only two tiers of holes; one of three or four for the ash-pit, and another for the body of the furnace. A larger furnace may require more holes, and may at times have those which communicate with the ash-pit enlarged into other forms, and furnished with stoppers of soft red brick (1354), or pieces of old pots.

162. The fuel used with these furnaces is charcoal, or in the larger ones charcoal mixed with coke.

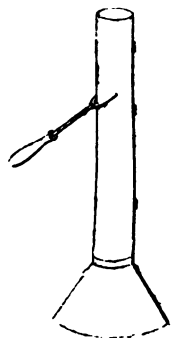
163. The fire is considerably under command, both as to the diminution and increase of its intensity. A box of round stoppers, made of soft brick (1354), or old blue pots, and something like corks in form, should be provided. These serve to close the air-holes which lead either to the ash-pit or directly to the fire, and, by limiting the quantity of air which enters, reduce the combustion in any required degree. When the grate is placed high up in the furnace, as for distillations, these stoppers are frequently required for the lower holes.

164. On the contrary, to increase temperature, and sometimes to increase the body of fuel, additions are made at



the top of the furnace. A very useful one consists of the upper part of an old crucible, cut off so as to form a ring, which should be bound with wire, as was directed in regard to the furnace (159). Rings of this kind may be from an inch to three inches or more in depth; and when placed upon the top of the furnace, so as to form a continuation of it in height, they considerably increase both the capacity and the draught. They may be made with holes or not, according to their depth. Such holes of course weaken the ring, but when the quantity of fuel in the fire is increased, it is frequently necessary to increase the supply of air also; and when a crucible stands in the middle of the mass of fuel, these lateral supplies of air, especially in the smaller furnaces, are essential to the vividness of combustion, and the high temperature required.

165. A most useful accompaniment to these small portable furnaces is a piece of straight funnel-pipe, about two feet long, four inches in width, and opening out below funnel fashion, until it is about eight inches in diameter. This will easily rest upon any furnace not more than eight inches, nor less than four or five inches wide; is quickly put on or off; stands steadily of itself, and increases the draught powerfully. A wooden handle may be attached to it for convenience; or without it the tongs will serve to remove it. It

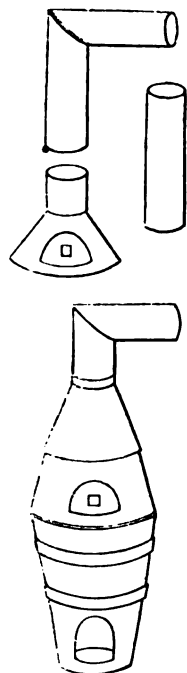


may either be taken off when the fire requires to be made up, or the pieces of charcoal may be dropped in from above. There is no difficulty in raising a crucible two inches and a half in diameter to a white heat, by a furnace of this kind, and of the dimensions before stated (158); and that in any situation which may be convenient, upon the tables or the floor, and with all the advantage of arranging or dismounting the apparatus with extreme facility. The ignitions and heatings which belong to the analysis of siliceous and other minerals, have long been made in furnaces of this kind at the Royal Institution.

166. To fit this furnace for the igniting of tubes, it is useful to cut a couple of notches in its upper edge, about an inch deep, in which the tube may be laid when the grate is high in the furnace; at other times when a smaller heated length only is wanted, it may be passed through two opposite holes lower down in the furnace. When heating a tube in this manner, it is not necessary to have a greater space than an inch or an inch a half between it and the grate.

167. When these furnaces are made out of large pots, the grates being upwards of six inches in diameter, and the fuel chamber six or eight inches high, they become very powerful, and may be used to heat crucibles of considerable size. From the larger dimensions of the grate, it is generally unnecessary to form lateral air-holes through the body of the furnace, but it is then requisite that an abundant supply of air be admitted to the ash-pit, and through the grate to the fire. The fuel used in these larger furnaces should be a mixture of coke and charcoal; or sometimes, when a durable fire is required for long operations, coke alone; for in such cases the rapidity with which charcoal burns away is inconvenient, and the heat which it produces may be attained with coke by improving the draught.

168. These furnaces may, when the employment of the highest heat is desirable, be advantageously connected with the spare laboratory flue (5), and the openings of that flue should be above the level of the furnaces when they stand on the floor. The communication is easily effected by



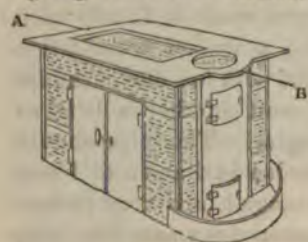
two or three short pieces of funnel-pipe like those in the margin, made to fit into each other; one having a funnel termination at the bottom, lined with fire-clay, to adapt it to the furnace, and another a bend or joint at right angles. The pipe should be at least four inches in diameter. These furnaces, thus arranged, are very powerful, and, being sometimes wanted for long operations, require to be fed without disturbance of the arrangement; for which reason it is proper to have an aperture in the funnel-pipe, by which fuel can be introduced, and which may be closed by a stopper, when the fire is in order. Another, and at times, a more convenient mode of arrangement, is to continue the furnace upwards by a deep ring (being the upper part of another pot), in which is an aperture by which the fire can be fed when required, but which can be closed by a stopper when not in use. The

funnel-pipe is then to extend from the top of this ring to the hole of the flue in the wall. These large furnaces should be bound with iron hoop.

For further information relative to these kinds of furnaces, see Lewis's *Philosophical Commerce of the Arts*, pp. 1—37.

169. The furnace next requiring description, is that intended for general laboratory use, and already referred to (8). Being in constant requisition as a table, it should be about 34 or 35 inches in height; its other dimensions, and even its form, must depend upon the space that can be allotted for it. The one in the laboratory of the Royal Institution, constructed several years since, under the direction of Mr. Brande, has the brick-work 52 inches in length, and 30 inches in width; the iron plate, including sand-baths, being 57 inches by 42; others have been constructed, the plates of which are only 40 inches by 27. The prin-

cipal part of this furnace is necessarily of brick-work, only the top plate, with the baths and the front, being of iron. The front is a curved plate, having two apertures closed by iron doors; one belonging to the fire-place, and the other to the ash-pit. It is 34 inches high and 14 inches wide. The ash-hole



door moves over the flooring beneath; the bottom of the fire-place door is 22 inches from the ground, and the door itself is $8\frac{1}{2}$ inches by 7. This front is guarded within at the part which incloses the fire by a strong cast-iron plate, having an opening through it corresponding to the door of the fire-place. It has clamps attached to it, which, when the furnace is built up, are inclosed in the brick-work.

170. In the setting or building of the furnace, two lateral brick walls are raised on each side the front plate, and a back wall at such a distance from it as to leave space for the ash-hole and fire-place; these walls are lined with Welsh lumps, where they form the fire-chamber: two iron bars are inserted in the course of the work to support the loose grate bars in the usual manner, the grate being raised 19 inches from the ground. The side-walls are continued until of the height of the front, and are carried backward from the front in two parallel lines, so as to afford support for the iron plate which is to cover the whole. The back-wall of the fire-place is not raised so high as the side-walls, by six inches and a half, the interval which is left between it and the bottom of the sand-bath being the commencement of the flue or throat of the furnace. In this way the fire-place, which is fourteen inches from back to front, and nine inches wide, is formed, and also the two sides of the portion of horizontal flue which belongs to the furnace, and is intended to heat the larger sand-bath. The bottom of this part of the flue may be made of brick-work, resting upon bearers laid on the two side-walls, or it may be a plate of cast-iron resting upon a ledge of the brick-work on each side, and on the top of the wall, which forms the back of the

fire-place. When such an arrangement is adopted, the plate must not be built into the brick-work, but suffered to lie on the ledges, which are to be made flat and true for the purpose; for, if attached to the walls, it will, by alternate expansion and contraction, disturb and throw them down. The ends of the side-walls, forming as it were the back of the furnace, may be finished either by being carried to the wall against which the furnace is built, or inclosed by a piece of connecting brick-work, to make the whole square and complete, or a warm air cupboard may be formed in the cavity beneath the flue, and the door made to occupy the opening between the walls. Occasionally the flue may be required to descend there, and pass some distance under ground. These points should be arranged and prepared before the plate constituting the top of the furnace is put on to the brick-work, so that when the plate with its sand-baths are in their places, they may complete the portion of horizontal flue by forming its upper side.

171. The size of this plate is the first thing to be considered; and having been determined upon, from a consideration of the situation to be occupied by the furnace, and the places of the sand-baths having also been arranged, the brick-work must then be carried up, so as to correspond with these determinations, and with the plate itself, which in the mean time is to be cast. The sand-baths and the plate are to be formed in separate pieces. The bath over the fire is best of a circular form, and of such diameter that, when lifted out of its place, it may leave an aperture in the plate equal in width to the upper part of the fire-place beneath; so that a still or cast-iron pot, or a set of rings, may be put into its place over the fire. The other sand-bath must be of such a form as to correspond with the shape and size of the flue beneath. These vessels are to be of cast-iron, about three-tenths of an inch thick; their depth is to be two inches and a half or three inches, and they are to be cast with flanches, so as to rest in the corresponding depressions of the plate, that the level of the junctions may be uniform. This will be understood from the accompanying section of the furnace, given through the line

A B of the view (169). It is essential that these sand-baths



be of such dimensions as to fit very loosely into the apertures of the plate, when cold, a space of the eighth of an inch or more being left all round them, as shown in the section; otherwise, when heated, they will expand so much as entirely to fill the apertures, and even break the plate. The plate itself should be half an inch thick.

172. When the plate and its sand-baths are prepared, and the brick-work is ready, the furnace is finished by laying the plate on the brick-work, with a bed of mortar intervening. If the walls are thin, or any peculiarity in their arrangement occasions weakness, they should be bound together within by clamps built into the work, and without by iron bands. The alternate changes of temperature from high to low, and low to high, to which the furnace is constantly subject, render it liable to mechanical injury, in a degree much surpassing that which would occur to a similar piece of brick-work, always retained nearly at one temperature. The square space inclosed by the fire-place and flues may be converted into an excellent drying or warm air chamber if desired (608).

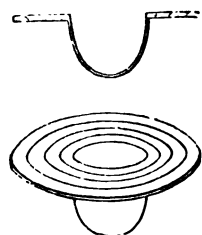
173. The sand-baths which have been described are liable to an accident, that has induced some chemists to substitute others made of wrought iron. When first heated they frequently, indeed generally, crack from the unequal expansion in different parts; and the plate itself is subject to the same accident. If constructed of wrought iron, this effect is not produced; but then after being used for some time they warp into very irregular and inconvenient forms, especially if made of thin metal; whilst, on the contrary, these of cast-iron, when cracked, are rarely injured for the uses to which they are to be applied, and seldom suffer further change.

174. These baths should have washed river or sharp sand put into them (24); it is heavy, and occasions no dust when

moved; whilst, on the contrary, unwashed and bad sand contains much dirt, and occasions great injury in experimenting. A piece of straightened iron hoop, about twelve inches in length, should lie on the furnace, as an accompaniment to the baths, being a sort of coarse spatula with which to move about the sand (256, 381).

175. These baths are frequently used not for their especial objects, but for the purpose of supplying heat generally to the laboratory; for the sand being cleared off the bottom of the bath towards one end, leaves the metal uncovered, which then rapidly communicates heat to the air, and acts with the full and economical effect of a stove. The same arrangement produces a current of hot air upwards, which may frequently be used to warm apparatus, to heat plates for drying filters, &c.

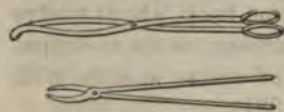
176. The circular sand-bath is frequently replaced by a set of concentric iron rings, or a cast-iron pot. The rings are convenient for leaving an aperture over the fire of larger or smaller dimensions, according as a smaller or larger number are used at once; and being bevelled at the edges, fit accurately into each other, without any risk of becoming fixed by expansion. The external one, like the sand baths (171), should be made smaller than the depression in the furnace-plate in which it rests. The iron pots are of various sizes, and are adapted to the furnace by means of the rings; a red heat for sublimation is easily obtained in them.



177. Occasionally the sand-bath is replaced by a still, for the production of distilled water (26). The form of the aperture and furnace is such as to enable the still to be placed very advantageously as relates to the fire beneath.

178. Tongs are essential accompaniments to furnaces. There are many forms of these necessary implements; those which have the rivet in the middle of their length, so as to allow of considerable opening at their extremity, and also have the ends bent downward, are best for common use.

They should be of different lengths, from a foot to two feet; and there should be one or two pair having the rivet



near the extremity, by which a powerful hold is obtained, so as to prevent the slipping of a heavy weight from between them.

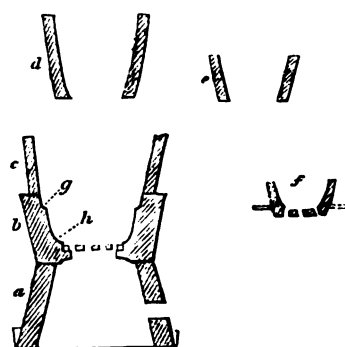
179. Mr. Knight, of Foster-lane, has contrived a small furnace, which, at the same time that it is competent for the performance of numerous chemical operations, is generally convenient for its lightness and portability. It is described with several others in many chemical works. The points of manipulation peculiar to each become evident upon inspection.

180. *Wind-furnaces* are such as have their combustion urged by a draught of air through them, dependent upon the flue to which they are attached. They are usual amongst refiners, and those who melt metals in pots, as well as in the laboratory; hence their improvement and perfection are of great importance. The table furnace already described (8, 169), and the crucible furnaces, when connected with the laboratory flues, are wind furnaces; but by proportioning the size of the chimney to that of the furnace, others may be constructed much surpassing these in the intensity of heat produced. It has been found that the combustion is most vivid when carried on in a furnace of equal diameter, with the flue placed immediately over it, the latter being of a height equal to about thirty times its diameter, and free access of air to the grate being permitted. But in practice, many variations are introduced, which, though they diminish the intensity of heat, still enable the worker of metals to heat a larger mass of matter up to the point he requires, with a diminished consumption of fuel, and consequently at a smaller expense.

181. In the laboratory of research, the wind-furnace may generally be replaced with advantage by the *blast-furnace*; the operations being more manageable and expeditious, the heat greater, and the consumption of fuel smaller. By a little contrivance, one of the crucible furnaces before de-

scribed (158) is easily converted into a blast-furnace, and a very high temperature for small vessels obtained. This is done by closing the holes of the ash-pit with the stoppers (161), except one, and applying to that the nozzle of a pair of double hand-bellows, from which a blast is to be urged, and the furnace aided at the same time by the piece of upright funnel-pipe (165); the fuel is to be charcoal.

182. Mr. Charles Aikin has devised an arrangement for a blast-furnace on a small scale, which is exceedingly good



and powerful. The furnace is made out of fragments of broken blue pots, and consists of several parts, sections of which are here given, drawn upon a scale of one inch to ten. The lower piece *a* is fitted into a tin bottom, consisting of a circular plate with a rising rim; the junction being made tight by plaster of Paris. The piece *b*, resting

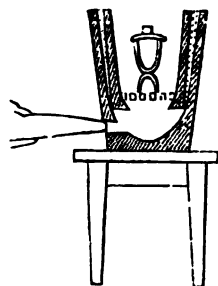
upon *a*, is so formed as to have three circular shoulders running round the inside, one at *g*, a second at *h*, and a third a little lower, namely, where the grate in section is observed to rest. The grate is circular, and can be removed at pleasure. The piece *c* is merely a broad rim, which, resting upon the edge of the piece *b*, increases the capacity of the furnace. The piece *d* is to be used when, in place of enlarging the fire, it is required to be diminished. It is to be placed within *b*, resting at its lower edge on the rim or shoulder *h*: *e* is a similar piece, but smaller, it rests also on the shoulder *h*: it has a notch half way between the upper and the lower edge, to admit the stem of a tobacco-pipe, or other similarly-formed article. Another part of the furnace is a circular plate of sheet iron, of such a diameter as to fit into the rim *g*; this plate is perforated with an aperture three inches and a half in width, into which a very small furnace-body fits, having its lower part pierced with holes instead of a grate; both these are represented at *f*.

183. When the furnace is in use, it is raised on a stand, and the nozzle of a pair of double bellows, twelve inches long and ten inches wide, brought towards the aperture in the lower piece, but not inserted. The fire is lighted by a piece of brown paper and a little small coal, and is sustained either with coke and small coal, or coke alone. The coke is sifted of two sizes, and preserved in boxes, with a ladle to supply it to the fire. When a fire of a moderate size only is wanted, the piece *b* is used; if there be occasion to increase it, *c* is put on. When smaller fires are required, *d* or *e* is used. For operations where tobacco-pipes replace ordinary crucibles, the grate is removed, and the piece and plate *f* placed within *b* at the shoulder *g*.

Mr. Aikin easily melts cast iron at this furnace, and can heat a crucible two inches and a half in diameter, and three inches and a half in height, to bright redness in a very short time.

184. The following is a description of a most excellent blast-furnace, which has been in use for some years in the laboratory of the Royal Institution. It is sufficiently powerful to melt pure iron in a crucible in twelve or fifteen minutes, the fire having been previously lighted. It will effect the fusion of rhodium, and even pieces of pure platinum have sunk together into one button in a crucible heated by it. All kinds of crucibles, including the Cornish and the Hessian, soften, fuse, and become frothy in it; and it is the want of vessels which has hitherto put a limit to its applications. The exterior consists of a blue pot eighteen inches in height, and thirteen inches in external diameter at the top. A small blue pot, of seven inches and a half internal diameter at the top, had the lower part cut off, so as to leave an aperture of five inches. This, when put into the larger pot, rested upon its lower external edge, the tops of the two being level. The interval between them, which gradually increased from the lower to the upper part, was filled with pulverized glass-blower's pots, to which enough water had been added to moisten the powder, which was pressed down by sticks, so as to make the whole a compact mass. A round grate was then dropped into the furnace, of

such a size that it rested about an inch above the lower edge of the inner pot: the space beneath it therefore con-



stituted the air-chamber, and the part above the body of the furnace. The former was $7\frac{1}{2}$ inches from the grate to the bottom, and the latter $7\frac{1}{2}$ inches from the grate to the top. Finally, a horizontal hole, conical in form, and $1\frac{1}{2}$ inch in diameter on the exterior, was cut through the outer pot, forming an opening into the air-chamber at the lower part, its use being to receive the

nozzle of the bellows by which the blast was to be thrown in. The furnace being thus completed, the next object was to dry it gradually, that when used it might not be blown to pieces by confined aqueous vapour; a charcoal fire was therefore made in it, and left to burn for some hours, being supplied with air only by the draught through the hole into the chamber beneath. When vapours ceased to be formed, the furnace was considered as ready for use.

185. This furnace has always been used with a pair of large double bellows mounted in an iron frame, the former being raised upon a stool so as to bring the aperture of the air-chamber to a level with the nozzle of the bellows. The latter has generally been inserted in the aperture; for this and similar furnaces are of such depth, compared to their width, that when charged with a crucible and fuel, there is so much resistance to the passage of the air, when urged by a blast competent to create and sustain a vivid combustion, that a part returns by the side of the nozzle, if the aperture be left open. The bellows spoken of is far larger than necessary for the furnace described, and is rarely worked to one-third of its power; for otherwise the heat rises so high as to destroy the crucible, and the results are lost; it is, however, at all times advisable to have an abundant command of air.

186 The heat produced by this arrangement is such, as at every violent operation, to cause the production of some slag from the melting of the inner surface of the furnace

itself, where the combustion has been most vivid. The slag, running down the interior, collects round the edge of the grate, and should be removed with a chisel and hammer, or with an iron rod, after each operation, that the grate may be clear and free from obstruction for the next process. When, in the course of time, the interior of the furnace is so far injured as to become thin and weak, it must be displaced, and the furnace restored to its original state, by the introduction of a new inside as before (184).

187. The fuel to be used in this furnace is coke. Its consumption is very small, considering the heat that is obtained, in consequence of the short period of each operation. The superiority of the blast-furnace over the wind-furnace in many operations for which high temperatures are required, depends upon the rapidity of its action. It is requisite to employ this furnace in the open air, or under a well arranged vent, for an immense number of sparks, much flame, and a current of hot air are produced during its operation, which might occasion serious mischief in a room, unless the ceiling were at a considerable height, or guarded by a metal screen.

188. In using a blast-furnace like the one described, some circumstances have to be considered relative to the method of applying the stream of air. If a small pair of bellows be used, the nozzle of which is considerably less than the aperture into which the air is propelled, then a much larger quantity of air is made to enter, if the nozzle be a couple of inches or more from the hole on the outside than if it be actually inserted; for, in the latter case, little more than the stream of air from the bellows is thrown through the furnace, whilst in the former a large additional quantity is propelled and drawn by the advancing stream, and carried in with it; just, indeed, as happens with the blow-pipe jet of air where the flame and neighbouring atmosphere is drawn into the current formed by the propelled central stream. Hence if the bellows be small and the fuel not too compact, advantage may be taken of this circumstance, and the heat more highly raised and sustained than if the effect in question were unattended to.

189. Priestley, and after him Lavoisier, proposed the application of oxygen to furnaces, to increase the rapidity of combustion, and consequently the intensity of heat: but it will evidently be unnecessary to employ it whilst furnaces in which common air is used continue to be more than equal to our means, in consequence of the limit put to their application, by the inadequacy of the vessels we possess to resist higher temperatures.

190. The *fuel* to be used in furnaces is of three kinds, coal, coke, and charcoal. *Coal* is the ordinary fuel for the laboratory table-furnace (8, 169), or that intended to be in use every day, and serve for fusions, roastings, and other operations, for which its temperature may be sufficient. It is very desirable that it should be good of its kind, and not that which contains much sulphur, or an abundance of earthy matter; for the first interferes with various fusions and ignitions, and the latter renders the fire dirty and dusty, and when the temperature is raised to a high point, causes an abundance of clinkers. On certain occasions, to be hereafter distinguished, especially if the coal be sulphureous and bad, it may be necessary to use both coke and charcoal in the table-furnace. Coal should never be used in the blast-furnace: for, in consequence of its softening and swelling by heat, it aggregates, closes the small channels by which the air finds a passage through the fuel, and impedes the combustion.

191. *Coke* is in constant requisition; it varies in quality with the coal from which it is obtained. Such as is intended for the service of the blast-furnace should be free from sulphureous, earthy, and metallic matter. Of this kind is the Staffordshire coke, which may be obtained at some of the wharfs on the canals near London. It is frequently so little altered in appearance as to resemble the original coal. It burns away completely in a blast-furnace, leaving scarcely a trace of slag: so that after several successive portions have been introduced, no material quantity of refuse is produced upon the grate, nor anything that will act seriously on the crucible as a flux.

192. On the contrary, if common gas-coke be used in this furnace, the oxide of iron and earthy matter which it contains is so abundant that slag is soon produced, which, flowing over the crucible, corrodes and destroys it; by mixing with the fuel, it tends to prevent the access of air to its surface, and by accumulating upon the grate, at last so far obstructs the entrance of air from beneath, as to prevent the attainment of a high temperature. This coke is not more than half the price of that from Staffordshire, and is very convenient and serviceable in the laboratory table-furnace, where, when an iron bottle is to be ignited, or a crucible heated only to bright redness, it answers far better as fuel than coal; and as it does not swell nor aggregate, the passage for air through the fuel remains open, and a general and regular heat is obtained.

193. The Staffordshire coke when used in the blast-furnace before described (184), should be broken into pieces somewhat larger than a walnut, that it may sink down in the fire between the crucible and the furnace, presenting a constantly compact body of fuel (673); and it should also be sifted or screened before it is used, to remove the dust and small particles, which otherwise being mixed with it, would interfere with the passage of the air, by stopping up the small vacuities between the different pieces of fuel as they lie in the furnace.

194. The *charcoal* intended for laboratory use may be of the ordinary kind, and must not be either too large or too small. If large the pieces should be broken down, or they will be unfit for use in the crucible furnaces, for which it is principally intended. Charcoal is a quick fuel; but burning with facility, a small quantity of it can be easily retained in a state of regular combustion; and hence in cases where but little space intervenes between the substance to be heated and the side of the furnace, or when a small temporary fire is required in the air, it is very convenient. Where Staffordshire coke will burn, and by means of a blast or a draught of air will give sufficient intensity of heat, it is very superior to charcoal in duration. Occasionally, a mixture of coke and charcoal is convenient, since it affords a combina-

tion possessing the qualities of permanency and freedom of combustion.

A charcoal box is almost as essential to a laboratory as one for coal, and should have its appointed place.

195. It frequently happens, that instead of a regular furnace fire, a temporary arrangement is much more advantageous; thus, a fire of pieces of charcoal may be arranged upon a plate of iron or tin, or upon a piece of iron-wire-work, and be far more applicable than one in a furnace. Sometimes an iron wire basket, like a common mouse-trap turned upside down, is very useful, and affords great heat, because of the access of air to all sides of it, whether urged by draught or bellows. A loose iron grate and a few bricks will often serve in the construction of a powerful little furnace; but these temporary arrangements must be left to be suggested by the wants, and applied by the judgment, of the experimenter.

196. It must be remembered, that all operations with furnaces should be carried on in safe situations, care being taken that no danger be incurred by the ascent of sparks, flame, or hot air; by lateral vicinity to combustible bodies; or by standing upon an unprotected wooden surface. When from peculiar circumstances a small furnace is necessarily placed in such a situation that danger may be anticipated from the ascending current of air, the latter may frequently be rendered harmless by fixing a plate of tin over the furnace, so as to break the current, and mix the hot air of which it consists with the neighbouring atmosphere. Injury from the vicinity of a heated furnace to wainscot, a trough, or any thing destructible by heat, may almost always be prevented by interposing a bright sheet of tin-plate; the heat being then reflected and the neighbouring body kept perfectly cool (1359).

197. When small furnaces are placed upon tables, stools, or trays, a brick, or a piece of sheet-iron or tin-plate should be interposed, according to the mode by which the heat is likely to be communicated (1357): a brick or tile should be used in cases of conduction, metal in sheets to catch ashes,

and bright tin-plate to prevent the ill effects resulting from radiation. When a permanent furnace is erected in a room which, being floored with wood, is to be converted into a laboratory, great care should be taken that the ash-pit and parts adjacent be guarded by a stone flooring laid down for the purpose. The stones should be bedded in a proper manner beneath, that no injury may arise should cracks occur in them, or in case they should not be of sufficient thickness to prevent the transmission of heat.

§ 2. *Lamps.*

198. Lamps may be considered as small furnaces, and are very economical and ready sources of heat. Nor are they deficient in temperature; for the intensity of heat in flame is very high. Since the method of operating on small quantities of matter has been practised and improved, not only has the heat of a simple unassisted lamp-flame been taken advantage of, but many contrivances have been practised by which it has been powerfully increased and more beneficially applied.

199. Of the varieties of lamps used in the laboratory, the most useful is that in which spirit is burned. Spirit lamps may be bought at the instrument-makers, and are to be trimmed with a cotton wick and supplied with alcohol. When in combustion, the flame, though pale, produces intense heat, as may be proved by introducing a small platina wire or other piece of filamentous matter into it. The student should in his first practice accustom himself to the introduction of small fragments of minerals, metals, and other substances, into the flame, at the extremity of a thin wire, or a filament of asbestos, or upon a narrow slip of platina foil. He will thus habituate himself to various appearances, obtain a knowledge of the heating power, and learn from experience at what part of the flame the highest temperature exists, and where he should intersect it when he wishes to obtain a more moderate but more general heat.

200. The flame of alcohol produces no smoke or fuliginous

matter, and hence a great and constant advantage possessed by it. If a platina capsule, or a small platina crucible, be held in the flame of a candle, for the purpose of applying heat to its contents, a black sooty film is soon deposited, which from its great radiating power occasions the loss of heat, and prevents that elevation of temperature which the flame otherwise is competent to produce. But held in the flame of a spirit lamp, the blackening does not take place, and this circumstance is one great cause why the rise of temperature is to a much higher degree in this than in the former instance. If a candle were used to apply heat to the exterior of a glass flask or retort, the carbonaceous matter would soon accumulate, so as to obscure the vessel and hide the contents; but a spirit lamp occasions no such obscuration, and at the same time that heat is applied, the utmost facility of observing the substances within is afforded.

201. Where the flame comes in direct contact with the substance under experiment, the advantages are equally on the side of the spirit lamp. For the carbonaceous matter, besides interfering as above described, would frequently have an injurious chemical effect; whereas it seldom happens that the water and carbonic acid which result from the combustion of alcohol, produce any change by their contact.

202. The place of greatest heat in the steady flame of the spirit lamp is just within its summit. The substance to be heated, when it will bear the direct contact of the flame, should be as small as possible, consistently with the power of duly observing its changes. It may be supported by a pair of delicate platina forceps, or at the end of a piece of fine platina wire or foil; or when the substance will admit of splintering, may itself be the extreme end of a sharp splinter, and will then require no other support. In all cases the support should be as thin and delicate as possible, that the heat may not be conducted by it from the substance to be examined, or the flame itself cooled by contact with it. Occasionally, especially when the support is platina wire, it is advantageous to make that part of it which is next the substance as hot as possible, that its tendency to conduct

heat from the body to be ignited may be diminished. This is easily done by holding it so that the wire shall ascend as it were up the side and just within the verge of the flame, still supporting the body to be heated in the hottest part; or at times it is sufficient to let the support descend from above, the hot air from the flame heating the part next to the substance to a sufficiently high temperature.

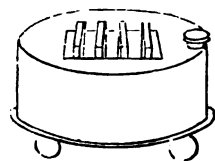
203. When a larger substance is to be heated, it is generally best done by putting it lower down in the flame than the hottest point, the flame being made to divide under it, and ascend a little distance on all sides. In this way a small platina crucible or capsule may be heated red-hot throughout; whereas, if put at the summit of the flame, such effect would not be produced, because of the partial exposure of the vessel to the surrounding air.

204. Platina foil is a useful accompaniment to the spirit lamp. A square inch of its surface may be made at once red hot. It may be readily bent into any convenient form, so as to supply the place of crucibles and capsules for small quantities of matter. It suffers scarcely any change by heat, is affected by few bodies except sulphur and the reduced metals, and withal is so bad a conductor of heat that it conveys less from substances lying upon it than any other metal, and does not conduct an inconvenient quantity to the fingers (1353). If pieces of platina foil, about an inch or an inch and a half in diameter or width, be put into a small mortar and pressed upon and moulded with the pestle, they will form excellent capsules for numerous purposes of ignition (371). These may be supported by the wire holders (666).

205. Spirit lamps of the usual size will give a flame of any height less than two inches, the wicks being of twisted cotton, usually about a quarter of an inch in diameter; but a lamp with a larger wick is desirable in the laboratory. One made of copper, with a burner one inch long, by the third of an inch wide, will produce a flame in which a platina crucible nearly two inches in diameter, and small glass retorts, may be heated to redness.

206. A very powerful and useful spirit lamp, frequently

supplying the place of a furnace, is formed by making an aperture of 0.8 or 0.9 of an inch by $1\frac{1}{2}$ inch, through the body of the lamp, and fixing in it four burners, upon Count Rumford's principle, each of a length equal to the width of the aperture, and the $\frac{1}{8}$ or $\frac{1}{16}$ of an inch wide. These



are to be parallel to each other, and at such distances as to have five spaces or air ways, the two outer being half the width of the inner. These burners rise about a quarter of an inch above the lamp, and descend as low as the bottom of the body, being fastened in the aperture by their edges. Each burner is closed beneath, but has a small hole into the lamp as a passage for the alcohol, thus forming as it were a part of the lamp. The lamp is supported upon four balls about half an inch in diameter, to allow of the access of air beneath and up the apertures to the flame. The alcohol is introduced by a hole in the upper surface of the lamp, which is usually closed by a screw; and the burners are trimmed by putting down each a doubled cotton of an Argand lamp until it touches the bottom, and then cutting it off about the eighth of an inch above the top.

207. Such a lamp is very powerful when applied merely as other spirit lamps are to the vessels to be heated, but it becomes still more effectual in heating a crucible when assisted by a chimney. This may be, as usual, a copper cylinder, resting below upon the flat surface of the lamp, and either level at the top or cut out into three or four large scollops. Two chimneys are useful, of an inch and three quarters in diameter each, one about three and a half, and the other five inches in length. Such a lamp, besides having the power of heating crucibles and retorts, is easily adjusted in any convenient place, soon set to work, and as soon extinguished;



and if convenient, only one or two wicks may be lighted at once, those which are not employed being covered up by the caps which are used to slip over the burners to prevent evaporation when the lamp is not at work. The jackets

hereafter to be described (667), may be considered as the chimneys of common spirit lamps; and if furnished each with three wire legs so as to raise the lower edge of the jacket about half an inch above the top of the lamp cotton, are very useful in rendering the flame steady and powerful.

208. It would be improper to omit mentioning Mr. Phillips's spirit lamp*, the advantage of which consists in its ready construction in any place and by any person. "Let a piece of tin plate about an inch long be coiled up into a cylinder of about three-eighths of an inch in diameter, and if the edges be well hammered it is not necessary to use solder. Perforate a cork previously fitted to a phial, and put a cotton wick through the short tin tube, and the tube through the cork; the lamp is now complete, and will afford a strong flame, taking care of course not to prevent the rise of the spirit by fitting the cork too closely."

209. All these lamps should have caps for the burners, to prevent the evaporation of the alcohol when they are not in use. Those which are sold in the shops are always furnished with them. The large spirit lamp above described should have one for each burner, the material being tin plate. Mr. Phillips's lamp may easily have a cover made for it by a little piece of glass tube closed at one extremity, fitting over the burner on to the cork.

210. Alcohol is the fuel burned in these lamps, and though it need not be highly rectified, yet the stronger it is the better. The spirits of wine of the distillers, or doubly rectified spirit, is sufficiently good for the purpose, the specific gravity of which is about 0.84 or 0.85.

211. There is a substance produced in considerable quantity, during the destructive distillation of wood, called Pyroligneous spirit, or Pyroxylic spirit. It is more volatile than alcohol, but burns very well in a spirit lamp. It has a peculiar odour, but in consequence of its cheapness has an advantage, its price being only sixteen shillings per gallon. It may be obtained at Apothecaries' Hall; at Morson's, Southampton-row; at No. 201, Strand; and at many other places.

212. *Oil* is a fuel so applicable in the service of lamps,

* Annals of Philosophy, New Series, vii. 36.

and also so economical as compared to alcohol, that oil lamps must not be omitted in the enumeration of sources of heat. Such as are constructed upon Argand's principle, having circular wicks with a current of air both inside and outside, are most valuable. They are now constantly constructed for laboratory service, the material being copper, and the chimney, in place of glass, being also of that metal. Their principal use is in distillations or evaporations, for they possess the advantages of yielding a nearly uniform heat for several hours together, and allowing its increase or diminution within certain limits at a moment's notice (439, 448, 465). It sometimes happens, that the highest temperature, or greatest quantity of heat of which these lamps are capable, cannot be attained, because, notwithstanding the careful and regular manner in which they have been trimmed, one part of the flame will smoke, if the wick be turned as high as the rest of the flame will bear, without smoking. Upon examination it will generally be found that the part which smokes is that coinciding with the notch by which the arm, connecting the cotton ring with the rack, descends; in which part the cotton is necessarily more exposed than elsewhere. Should it be so, the fault is easily corrected for the time, by placing a little slip of copper or tin plate against the cotton in that place; and then the other parts may be raised so high as to give their full combustion without smoke.

213. Double concentric-wick oil lamps have been constructed for the purpose of permitting greater combustion, and supplying more heat. These frequently fail in their applications, and generally because both cottons being attached to one rack, which is necessarily placed considerably on one side, there is great irregularity of action, and too much friction, whence the lamp soon becomes deranged, and is rendered useless. This evil is readily corrected by having two racks, the second being attached to the double cotton ring exactly as the first is, but on the opposite side; and then with care the lamp may be arranged with accuracy, producing as much heat as may be required for crucible operations (666). The racks should be raised or lowered

regularly and equally, so that both may assist in moving the cotton; and care should be taken that one be not raised without the other, or the one made to pull against the other. In reference to the wicks also, more care is required with the double than the single lamps, in consequence of the difficulty of trimming the two cottons, so that the flame of one shall not have a greater tendency to smoke than the other. The best method is to cut them as seldom as possible, but instead, to allow them to burn regularly, and when extinguished and cold, to remove the hard crust and leave the singed edge of the cotton that will then be exposed, as undisturbed as possible. A careful attentive experimenter will in this way find no difficulty in keeping a double-wicked lamp in order, and will obtain all the benefit which it is capable of affording; whilst a hasty careless operator will never be able to make the cottons move easily, or burn without smoke, or obtain any advantage from the lamp over an ordinary one.

214. It is essential in these oil lamps that an abundant supply of air to the wick be allowed. As generally constructed, there is seldom sufficient air-way, especially in those with double wicks; and though they may burn moderately well at first, yet the accumulation of oil and dust soon interferes by stopping up the narrow apertures, and thus manifests the deficiency. It is advisable to use the best lamp-oil; for the constancy and steadiness of its flame, and brilliancy of the combustion, more than compensate for the higher price of the fuel.

215. The erection of *gas* works for public service is now so general in most large towns and in numerous private establishments, that the chemical gas lamp, which some years ago was a mere curiosity, has now become a valuable and economical auxiliary to the establishment of the chemist. The facility of management, and the regularity of flame, are even greater than with the Argand oil lamp, for by means of jointed or flexible tubes, in conjunction with the smallness of the burner from which the flame proceeds, as compared with the body of an oil lamp, it can be adjusted with the utmost nicety in any required position. The kind of

flame depends upon the form of the burner. A single jet, or a series of jets in a line, or a circular flame, or several concentric flames, may be obtained at pleasure, and thus the applications of the gas lamp to distillation, the igniting of crucibles, &c., may be made to surpass in number and effect those of the lamps already described. It is only requisite to have burners of the different forms required, capable of being attached by a ground joint or connecting screw to the gas-pipe, which has been laid down from the works.

§ 3. *Blow-pipes.*

216. The blow-pipe is an instrument which cannot be dispensed with in the laboratory; and, as is usually the case in contrivances for the attainment of any particular object, the most common is the most valuable. The chemist does not possess a more ready, powerful, and generally useful instrument, than the mouth blow-pipe, and every student should early accustom himself to its effectual use and application.

217. The forms which have been given to this instrument, and the materials of which it is constructed, are very various. All that is essential is a tube to conduct the air from the mouth, terminated by a small regular round aperture, by which the air can be thrown out in an undisturbed stream; and, that facility may be obtained in directing it, the lower end of the instrument is generally turned to one side.

218. The common blow-pipe is a long conical brass tube; two or three inches of the narrow end being bent, so that the termination is nearly at right angles to the other part of the instrument. In consequence of the gradual condensation of moisture from the breath in the tube, when the instrument is much in use, a small portion of aqueous matter is sometimes ejected through the beak into the flame, and upon the substance to be heated. This occasions an irregular flame, and sometimes does harm to the heated substance, and the blow-pipe is therefore improved, by having a chamber constructed at one part of it for the reception of such moisture;

the accumulated water being removed after the experiments are over. Dr. Black's blow-pipe is a conical vessel, close, except at the summit, to which the mouth is applied, and at a lateral aperture below, from which a small pipe proceeds, terminating in the nozzle or jet. This cone serves not merely to condense the moisture, but in a slight degree to regulate the pressure of the air forced through it by the lungs and mouth. Dr. Wollaston's instrument, on the contrary, has no chamber, but consists of two or three pieces of tube, which, when arranged together, form an excellent blow-pipe, and when dismounted, pack into the size of a small pencil-case.



219. The essential part of the blow-pipe is the jet or termination by which the air is thrown out. The aperture should be a smooth round hole, not leading suddenly inwards, to an irregular cavity, but enlarging in an uniform manner, so as to form a small regular conical channel, at least the third of an inch in length, gradually passing into the general air-way of the instrument. The exterior should also be regular in its form, and diminish by degrees to the aperture; that when a stream of air is forced through the blow-pipe, the external air surrounding the jet may coalesce gradually with the current, and not have the motion communicated to it disturbed by any external irregularities of form. Perhaps the best model for a jet is that obtained by drawing out a piece of cylindrical glass tube (1176), and cutting it off so as to leave an aperture of a proper size; the nearer those which are made of metal approach to this in form, the better they will act. The size of the aperture of a blow-pipe must depend upon the flame to be urged, and the substance to be heated; for ordinary use it may be one-fortieth or one-fiftieth of an inch in diameter.



220. The jets of blow-pipes are constructed of different substances, those being in this respect the best which are made of materials least liable to change. For this reason, and also because of the facility with which differently sized apertures may be used, they are frequently made in sepa-

rate pieces from the instrument, and arranged to slip on to the extremity at pleasure. From the small quantity of metal required in their construction, they may then be made of platina; and a conical form given to them closely approaching that of the model before mentioned. The single objection to jets with these delicate terminations, is the facility with which they are altered in form and injured: but it is only the careless who suffer in this way, for no one acquainted with the value of the instrument will voluntarily subject it to mechanical injury.

221. When a blow-pipe is not at hand, a very excellent temporary one may be made from glass tube. A piece, nine or ten inches in length, and about one-third of an inch in width, is to be drawn out in the spirit lamp, so as gradually to diminish in diameter (1176, 1180), and then to be cut with a file, that its extremity may imitate the jet before figured. It is afterwards to be softened and bent on one side (1154), about two inches above the jet, and thus a perfect instrument for the time will be obtained: it is unfortunately brittle, and the jet is liable to fuse and become closed in the flame when the current of air is suspended; otherwise it would supersede most of the common blow-pipes.

222. The first point to be acquired in the use of the blow-pipe, is the practice of the mouth. It is easy by blowing through the tube in the usual manner, to produce a current of air, which if directed upon a lighted candle, will occasionally produce a clear and regular jet of flame. But this operation will soon be found uncertain and fatiguing, and recourse must be had to the action of the mouth and its muscles, not only to regulate, but, at intervals, to perform the whole office of supplying air to the instrument.

223. The practice necessary at first is that of making the mouth replace the lungs for a short time, by using no other air for the blow-pipe than that which it contains. This practice is simple in itself and soon becomes easy, but is difficult to describe. Let the student observe that it is easy, after having closed the lips, to fill the mouth with air, and to retain it so, at the same time that respiration may be

freely carried on, the air passing to and from the lungs by the nostrils. The mouth then resembles a close but distended bag, and the means being well observed by which it is thus for a time rendered independent of the lungs and nostrils as to air, let a blow-pipe, with a small aperture, be placed between the lips, and then again filling the mouth with air, let it be separated as before from the lungs: let the respiration be carried on as in the former case, but at the same time let the capacity of the mouth be contracted by the action of the muscles of the cheeks and jaws, and the air which it contained propelled through the blow-pipe. If the aperture be small, this operation will require ten or fifteen seconds, and being repeated a few times, a ready facility of using the blow-pipe, independently of the lungs, will thus soon be acquired.

224. This step being taken, the next is to combine this process with the ordinary one of propelling air directly from the lungs through the mouth, in such a way that, when the action of the lungs is suspended during respiration, the blast may be continued by the action of the mouth itself from the air contained within it. The mouth at this time represents the going fusee of a chronometer, which causes the works to advance during the interval that the direct action of the spring is taken off, by the hand which holds the key when the machine is wound up for the renewal of motive power. The time of fourteen or fifteen seconds, during which the mouth can supply air independently of the lungs, is far more than that requisite for one or even many inspirations; and all that is required to complete the necessary habit is, the power of opening and closing the communication between the mouth and the lungs, and between the lungs and the air, at pleasure.

225. The capability of closing the passages to the nostrils is very readily proved; every one possesses and uses it when he blows from the mouth; and that of closing or opening the mouth to the lungs may be acquired with equal readiness. Applying the same blow-pipe to the lips, as before, use the air in the mouth to produce a current, and when it is about half expended, open the lungs to the mouth

so as to replace the air which has passed through the blow-pipe; again cut off the supply as at first, but continue to send a current through the instrument, and when the second mouthful of air is nearly gone, renew it, as before, from the lungs. In this way acquire the power of using the air of one inspiration by mouthfuls, as it may be termed, not at any time letting the air from the lungs press upon that passing through the blow-pipe, except for the short intervals during which it is being renewed in the mouth; but measuring out as it were in successive portions, and giving the muscles of the cheeks and jaws the work of propelling it forward. This advance made, then, as the last step necessary, learn to fill the lungs whilst the mouth is independent of them, and occupied in propelling the air; and this cannot be difficult for many minutes to those who have already done the same thing for ten or fifteen seconds together, as just described. Once effected, let this second inspiration of air be used as the first was, and in the course of three or four inspirations, the student will find no further difficulty in understanding the succession of actions which are necessary to the production of a continued stream of air, and in performing them either separately or in order, as may be required.

226. The description of these processes is necessarily tedious, and the performance of them for the first time laborious and tiresome. The pupil should not endeavour in these trials to produce a strong current of air, as that occasions unnecessary fatigue. The smallest stream is as efficient as a larger one. The art once obtained, it will be quite unnecessary in actual practice to repeat the effects in the order they have been described. The peculiar action of the mouth is not necessary to a continued stream of air, except as connecting the air of one inspiration with that of the next, and continuing the current whilst the experimenter is inhaling; that effected, the mouth need not be resorted to, except for peculiar purposes, until fresh air is wanted, and inhalation again necessary.

227. In fact, however, the mouth, besides continuing, regulates and modifies the blast; and the muscles belong-

ing to it, being more powerful than those which command the lungs, are competent to the production of a much stronger stream of air. This upon occasion is very useful and important. The action of the mouth frequently helps to sustain and regulate the propelling force of the lungs, and frequently, also, when a stream of air for a long period of time is required, the mouth is advantageously used to propel and continue it whilst four or five inspirations are made: the lungs are thus relieved and refreshed, and this being repeated from time to time, takes from the operation a great portion of its labour.

228. The powers of the blow-pipe will, in the laboratory, frequently be added to those of the spirit lamp, especially in the heating of capsules, small platina crucibles, platina foil, glass tubes (666), &c. But when a very intense heat over a small extent only is required, it would appear that other fuel than alcohol is better for the purpose. A tallow or a wax-candle, or an oil lamp, with a wick about three-tenths of an inch in diameter, affords a very convenient flame. Sometimes the wicks of lamps are made broad and flat, for the purpose of supplying a greater body of flame when required.

229. The lamp, if one be used, being trimmed so as to occasion its full ordinary combustion, the jet of the blow-pipe is to be placed in a horizontal position opposite the flame, about the eighth or tenth of an inch above the wick; and a steady blast of air being thrown from it, it will be found that the flame loses its ordinary form and appearance, and is projected as a luminous pencil along the course of the stream of air. It should be steady, constant, and noiseless, not quivering, uncertain, or roaring. A small proportion at its commencement should be brightly luminous, but soon pass into a clear blue conical flame, towards the end of which on the exterior, another should begin to appear of a pale lambent yellow colour, and continue to an inch or more beyond the termination of the blue flame prolonging the cone. The end of the blue flame should be round, well defined, and even sharp in its outline. As the jet is advanced towards, or into, or withdrawn from the

flame, so does the latter vary in its size, shape, and steadiness; and as the power of changing it is useful, the extent to which it may be carried should be ascertained and practised.

230. If a candle be used, it should be snuffed, but not short, the wick inclined a little on one side, and the current of air from the jet sent obliquely upwards. If sent horizontally, the heat soon melts the tallow or wax on the side beneath the flame, and causes it to run down. The candle will frequently require snuffing, and should never be allowed to have any useless wick. The disadvantage of oil lamps is, that they also require frequent trimming, and in that respect are not so convenient as candles.

231. The lamp or candle should be low, that whilst using the blow-pipe the arms may rest steadily upon the table. The hands should lay hold of the instrument as far from the mouth as convenient, greater freedom of motion and steadiness being thus obtained, and the left or the right hand should be used indifferently. It should be the constant endeavour of the student when he is using the instrument, to obtain the power of so apportioning his breath, and of retaining the instrument and the flame, that the latter shall appear like a fixture, and neither change in appearance nor direction for several minutes together; yet this with such lightness of touch and easy hold, that he may at pleasure send the flame in any direction and upon any place he pleases.

232. The point of highest temperature in the flame is just at the extremity, on the exterior of the blue cone. Here the combustion is complete or nearly so, and has suffered least from cooling agencies; but there are other parts of the flame which, because of their peculiar qualities, demand a few distinct observations. On the outside of the blue flame combustion is complete; all the fuel is burnt, and the oxygen of the atmosphere in which the flame is formed begins to appear in excess, and from thence increases outwards. Hence the power of oxygenation to a great degree, in consequence of the elevation of temperature and the free oxygen existing there. On the contrary, within the

blue flame combustion is still going on, consequently combustible matter is present; there is no free oxygen, and a reducing agency is exerted. Berzelius well recommends that the situation and powers of these parts of the flame should be learned by operating on a globule of tin about the size of a shot placed in a small cavity on charcoal; the metal will be converted into a white crusty oxide, or be reduced and appear in the metallic state as a brilliant fluid globule, according to the part of the flame directed upon it and the skill of the operator.

233. When the temperature required is not particularly high, but the substance to be heated is large, a greater flame is to be used (666). It may be obtained from the alcohol lamp, or from an oil lamp with a flat wick, the current of air being directed along the edge of the cotton. A jet with a large aperture may then be employed, and it is occasionally advantageous, by a more powerful or more abundant blast, at the same time withdrawing the jet a little from the flame (229, 245), to break down the quiet tranquil intense cone into a roaring flame, the latter having power to heat a greater extent of surface than the former. A crucible or a capsule may be thoroughly ignited by a broken flame; but the same instrument and lamp with a steady flame, though they will heat one part intensely, would leave another part comparatively cold. In heating a glass tube for the purpose of bending or blowing it out, the same advantage is obtained; and it is a mistake to suppose the blow-pipe is useful only for the purpose of increasing and concentrating heat, it being in the laboratory frequently as advantageous merely for directing it. When the mouth blow-pipe is used with the large spirit lamp before described (205), a platina crucible one inch and a half in diameter may be heated red hot throughout, and a glass tube of considerable thickness be ignited regularly all round and softened so that it can be bent. With a smaller lamp or a candle, the blow-pipe is constantly in use for melting cement or other fusible bodies upon particular parts of apparatus, or warming the sides or tops of glass vessels; and it is for these amongst other purposes that the power of

directing the flame upwards or downwards, or in any direction at pleasure, is required.

234. The current of air is hot to a great distance beyond the flame, and should have its direction and power well appreciated by observation and experiment. It is frequently useful in warming vessels, and the student will best learn its capabilities by holding pieces of paper in its course, at different distances (1142).

235. The theory of the blow-pipe is simple: its powers depend upon the perfect combustion of the fuel, and the rapid succession of hot gaseous matter against the substance to be heated. The force which propels the stream of air through the instrument is so much greater than the ascending force of the heated gaseous products of the combustion, that the usual currents are altogether altered: the surrounding atmosphere from the sides and behind the jet of the blow-pipe, including the flame, is drawn in, and made to coincide with the propelled stream of air, so that not merely is the common form and direction of the flame destroyed and new ones given to it, but with such power that the ordinary and fluctuating motions of the atmosphere have little or no effect upon it. The heated particles rapidly succeed each other in an invariable direction, and as relates to the position of its parts, a degree of permanency is thus given to the flame. The point at which the particles attain their highest temperature continues the hottest so long as the current is unchanged, and when a body is placed there, it receives the successive action of these particles, and is itself raised to the highest possible temperature. By far the greater portion of the effect is due to the circumstance that the moment a particle of flame has touched the body and been cooled by communicating heat it is carried off by the current, and replaced by other particles of the flame at a maximum temperature. All loss of heat from the body by contact of colder particles is therefore prevented, and the elevation of temperature is limited entirely by the temperature of flame, radiation, and the deteriorating effects due to the conducting power of the supports.

236. For the attainment of the highest possible temperature in a body subjected to the powers of a flame urged by the blow-pipe, it is necessary to attend to other circumstances besides choosing the hottest place in the flame. It is found in practice, and easily explained by theory, that within certain limits the smaller the particle to be heated the higher will be the temperature acquired. Hence a reason for diminishing the size of the piece as much as possible. Then the supports should be such as, presenting the smallest quantity of matter by which the heat may be conducted away or otherwise dissipated, shall still resist the high temperature necessary to be borne where in contact with the substance, and shall also exert no chemical action upon it, or at least none that can interfere with the properties to be observed. For these reasons platina wire, or a thin slip of platina foil (204, 1353), is frequently used as a support; and forceps are constructed with delicate terminations of platina for the purpose of holding such solid particles as will not act upon them. These are frequently made with a pair of strong steel nippers at the opposite end, to break or chip off small splinters from minerals or brittle bodies. When a thin splinter can be detached, the fine edge or point is frequently more favourable for high ignition than a whole fragment, however small, supported in any other way.

237. Mr. Smithson* used small plates of clay as supports for substances before the blow-pipe. They are formed by extending a white refractory clay by blows with the hammer between the fold of a piece of paper like gold between skins. The clay and paper are then cut together with scissars into pieces about four-tenths of an inch long and two and a half tenths of an inch wide, and hardened in the fire in a tobacco pipe. When cut into small and very acute triangles, they form a substitute for Saussure's sappare. The method of attaching the particle to be heated to the end of these strips, or what is perhaps still better, to the end of a fine platina wire, which was afterwards adopted

* *Annals of Philosophy, New Series*, v. 387, vi. 412.

by Mr. Smithson, is to mix a very refractory clay with water; the least quantity of this is to be taken up at the very end of the clay strip or the wire, and the particle chosen touched with it: in a few moments it is dry, and may be introduced into the flame with perfect safety. In this way the smallest observable pieces may be readily experimented with. Sometimes the powder of the substance may be made into a mixture with water, and used instead of the clay for attaching a particle to the end of the wire.

238. Lieut.-Colonel Totten* varied these methods by making the pulverized substance into a paste with thick gum-water, and forming it between the fingers into small acute cones, the fourth or fifth of an inch in length. When dry they may easily be held at the end of a wire or in forceps, and the apex being moistened and directed to the particle to be experimented with, adheres to it, and will allow it to be subjected to the highest heat of the blow-pipe without suffering derangement.

239. In all experiments upon minute particles, or upon splinters, it will be necessary to examine the results with a glass, and not to trust to the naked eye. Appearances of fusion or porosity will frequently escape the unassisted eye, when very evident under a lens.

240. When charcoal is used as a support for the substance to be heated, whether for the sake of convenience of form, or on account of its chemical relations to the body, that should be chosen which has been made from young succulent wood, has thin bark, and is without cracks or cavities. Alder wood charcoal is by far the best, being soft and generally free from divisions. It may be distinguished by the triangular form of the pith. When used, a little cavity may be made with a knife on its convex surface, or sometimes even at the end of the cylinder where the cross fracture has left a smooth termination, and the substance being placed there, the flame is to be sent obliquely down upon it. Small charcoal, from two-thirds of an inch to an inch in diameter, is most convenient, because of its easy

* *Annals of Philosophy*, New Series, ix. 73.

approximation to the lamp or candle. It would be difficult to send the flame perpendicularly into the cavity, nor, if it were easy, would it often be desirable; for the propelled flame would return upon itself, and causing irregularity in the stream, would fail to produce the usual temperature. The blast should be generally propelled obliquely, that the flame entering over one side of the cavity after having struck upon the matter to be heated, may rebound a little and pass out by the other.

241. For ample directions in the management and use of the mouth blow-pipe, with all that relates to the characters and tests of substances examined by it, the student is referred to Berzelius's Essay*; which being essential to those who would apply the instrument to its full extent, or beyond what are its ordinary uses in the laboratory, renders any further account of it here unnecessary.

242. The next useful instrument of this kind in the laboratory, is the table blow-pipe. It consists of a small table, furnished beneath with a pair of double bellows worked by the foot. A tube is connected with them, which rising through the table is made adjustable above by sliding or moving joints, and terminates in a jet. This jet is of course larger than that of the mouth blow-pipe, being intended to urge a stronger flame, but still it should be smooth and well-formed (219), and its aperture round and symmetrical. It is almost always the work of the instrument-maker, but when a temporary jet is required, it may be obtained excellent of its kind, by drawing out a piece of narrow thick green glass tube in the manner before described (221). The lamp (always sold with the table, though separate from it) should have a burner competent to hold a bundle of twisted cotton half an inch thick and an inch wide, the top of the burner being about two or three inches from the table, that the jet may easily be adjusted to any required position. Tallow or dripping is, perhaps, the most powerful fuel for it; but in the laboratory, where it is often wanted at a moment's notice, oil is the most convenient.

* Berzelius, on the Use of the Blow-pipe, 8vo.

243. After having trimmed the lamp, leaving the cotton in a compact wick, rising about one-third or half an inch above the burner, light it, and place it on the table before the jet; then sitting on a chair with one foot on the treddle, work the bellows slightly, and arrange the jet by moving the joints of the tube, until, being horizontal, or nearly so, its extremity is a little above the cotton, and close upon, or just within, the edge of the flame. The force of the blast should be such as to gather the flame and make it proceed in the same direction with the jet, without any upward inflection of its extremity. If, for want of power in the jet of air, this be not at first attained, it should not be effected by working the foot so rapidly as to fill the bellows and drive the air out by the direct force exerted upon the treddle; but the upper board of the bellows should have weights placed upon it in such quantity as to cause pressure sufficient upon the air within to make it flow out with the required velocity. From the natural rigidity and tension of the leather, the pressure upon the included air will be greater when the bellows is nearly filled than when almost empty, so that the force of the blast may be varied by keeping the bellows more or less full, without any alteration in the loading weight. When an impulse is required stronger than that which can be produced by the weight and tendency of the bellows to collapse, more or less direct force may be superadded from the foot by means of the treddle.

244. The pencil need not necessarily include the whole of the flame rising from the wick, but as the remaining part throws off much smoke and fuliginous matter, it is better to conduct these substances away by a small hood and chimney. Such an arrangement has also the advantage of shading the bright part of the flame from the eyes, in consequence of which the progress of operations carried on in the pale part are much more readily observed. It frequently happens when the flame of the lamp is too large for the jet, that no attempts to force the whole into a clear steady cone will succeed; but upon advancing the jet a little way into the flame, a part will be thrown forward in the greatest perfec-

tion, whilst a portion behind the aperture will rise upright in its usual state, and almost undisturbed. It is even generally advantageous to have this superabundance of flame. The pencil of flame should be conical and steady, not ragged or broken, but ending in a blue point, passing into a pale phosphorescent halo, without any luminous or smoky part at the termination.

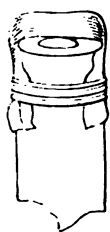
245. Modifications of this flame are required, resembling those described as useful with the mouth blow-pipe (233). When the jet is withdrawn a little way, and the blast impelled with considerable force, the flame is broken, roaring, and somewhat diffuse (229) ; it is then bluish, burns without smoke, and is useful in heating a crucible (666), or warming a thick glass tube.

246. When gas can be had in the laboratory (215), its application at the table blow-pipe is very convenient and very simple. The most useful arrangement is that where the extremity of the air jet is surrounded by the extremity of the tube supplying gas, the terminations of the two tubes being concentric. The gas aperture should be rather large, about a quarter of an inch in diameter, for then a considerable range in size of flame can be obtained from it ; if a still larger flame be required, it is easily obtained by making the terminations of the gas passage a shifting piece, so that different sizes may be put on. It is also an advantage if these pieces slide upon the gas-pipe in the manner of a telescope-joint, so as to allow of an adjustment in that direction. Practice will show the utility of the arrangement.

247. The construction of a temporary blow-pipe to supply, in cases of necessity, the place of a table instrument, is not difficult (1206). A pipe of glass, pewter, or any other substance, will convey the air ; and being tied to a weight or stand, or even a candlestick, may be arranged at the proper height, for its jet to accord with the lamp to be used. The first rough jet may be made by drawing out a piece of small glass tube in the spirit lamp, or a candle, and being attached to the apparatus, a second and proper jet may be made by means of it, out of a thicker piece of tube, and substituted for the smaller one (221, 1180). In-

stead of the bellows a larger bladder may be used, or, what is better, a bag made of oiled silk, or some of those fabrics now sufficiently common, in which cloth is rendered airtight by caoutchouc. This may be placed under one end of a board, with weights upon it, or within a portfolio, subject to pressure, and the air may be thrown into it from the lungs by another piece of tube sufficiently long to reach to the mouth. This tube will require a valve to prevent the return of the air; and the simplest that can be constructed for the purpose, in an extemporaneous manner, is perhaps the following.

248. A piece of any tube of about the diameter of that represented in the wood-cut, having a smooth and level end, is to be selected, and also a strip of black oiled silk, of a width rather more than the external diameter of the tube, or, if that be not at hand, a piece of ribbon of the same width, which has been rubbed with wax, so as to have the interstices in it filled up without destroying its flexibility. This is to be adjusted loosely over the end of the tube, and the extremities folded



down on opposite sides, and tied with a piece of thread; the silk itself not being so tight, but that by applying the mouth to the opposite end air may be easily blown through the tube, and out at the extremity between it and the silk; and yet so near that a pressure being exerted in the opposite direction, the silk will be carried against the end of the tube, and prevent the air from passing out again. The tube by which air is to be thrown into the bag from the mouth, is to have such a valve constructed at its extremity, which is to be introduced through a hole made in the bag, and tightly tied to it by a few turns of twine. So arranged, the bag is easily filled by air from the lungs, which being gradually expelled at the jet, gives energy to the flame. All the tubes required for this instrument, except the jet, may be made even of paper, in the manner hereafter to be described (1337).

249. A lamp for such a blow-pipe is soon fitted up; a bundle of cotton threads placed at the side of any small

vessel filled with oil will answer the purpose, and none is more convenient than a little Wedgwood's or evaporating basin.

250. The pneumatic blow-pipe is an instrument more portable than the table blow-pipe, and is intended to supply its place. There is nothing relative to its manipulation requiring notice, which has not been already mentioned.

251. Next to these ordinary forms of the blow-pipe, in which common air is used to urge the flame and increase temperature, come those which employ oxygen or other gases to heighten the effect: and by gradual improvement not only has the temperature, afforded by these instruments, been raised to an extraordinary degree, but at the same time with almost perfect security to the operator. It is only the most simple and effectual of these contrivances which will require attention, and of these merely such points as, from the facility of extemporaneous application, construction, or correction, may be most immediately instructive and useful to the student.

252. A very simple and powerful method of increasing temperature, the application and advantages of which were first shown by Dr. Marcet*, consists in urging the flame of an alcohol lamp by a blow-pipe supplied with oxygen gas. The oxygen may be furnished from an air-holder, a gas bag, or any other vessel, in which it has been stored. The flame is much smaller than when common air is used; it is also brighter, and its different parts have not the same relation:—for instance, when the flame is well urged, there is no point in which an excess of combustible matter can be found, or where deoxygenation can be carried on, as with the common blow-pipe (232), and hence it is never put to such purposes; or when applied to them, it only leads to negative or deceitful appearances. The hottest part of this flame is very near the mouth of the jet, the distance from it being not more than one-third or one-fourth that occurring when the same lamp is urged by common air (232). The oxygenating part of the flame (232) is, in the first place, the

* Thomson's *Annals of Philosophy*, ix. 21.

innermost: then there will usually occur a part where feebly reducing powers reside, and on the outside of that as before an oxygenating atmosphere again.

253. The use of hydrogen as fuel, instead of oil, alcohol, &c., has introduced many forms of apparatus (some of which are dangerous to beginners), intended for the special application of a mixture of it with oxygen gas. Dr. Hare was the first person who used these gases in conjunction, and described the effects produced. He sent them by different channels to the aperture, where they were mixed and burnt at the same instant. There was no danger in this arrangement, and the manner in which it may be repeated will easily be understood from what has been said, and the directions to be given relative to the manipulation of gases. The heat was very intense.

254. In consequence of the experiments made by Sir Humphry Davy, during the development of the principles of his safety lamp and researches into the nature of flame, in which it was shown that the flame of explosive gaseous mixtures would not pass back through small apertures or tubes; blow-pipes were soon constructed, in which the oxygen and hydrogen being mixed in the proportions necessary to form water, were then compressed in metallic boxes to the extent of many atmospheres. Small tubes were afterwards affixed to these boxes, and the mixed gases being allowed to pass out, were inflamed and burnt at the apertures of the tubes. Many circumstances combined to occasion accidents with this apparatus. The tube was at times too large, or it broke, or became heated, or the rapidity of the current in it diminished gradually, and the flame, retrograding under the action of one or more of these circumstances, ignited the mixture in the reservoir and caused explosion: and notwithstanding the numerous contrivances invented to prevent this return of the flame, there is not one, I believe, which from some unperceived or uncertain circumstance, either in the principles of the arrangement, or the accidents to which it is liable, has not failed at one time or another. Hence those only can be considered perfectly safe, where the reservoir of gas, as in Dr. Clarke's

arrangement, is separated from the operator by a wall or partition, of strength sufficient to give full security: and those are next, perhaps, where, as in the arrangement by Mr. Gurney*, the gases are confined in a receptacle so slight (a bladder), that if blown to pieces the fragments can hardly do harm. Then the only liabilities are, that the explosion itself shall shake and injure the neighbouring apparatus, or throw them about with an injurious violence.

255. There are still some points in the economy and application of heat, which require attention before we close this section, as best assimilating with its subject and matter. These principally concern the modes of heating by intermediate agents; some of which are of considerable general importance in the laboratory, others very valuable in peculiar cases.

256. All that relates to the general construction and arrangement of sand-baths has been already said (169, 176), except what will more properly come under consideration with the processes to be performed on them (381). Water-baths resemble sand-baths in offering a medium through which the heat can be applied to the substance to be heated; but differ from them in limiting the heat to temperatures below a certain point, and when required, in retaining it for any length of time near to one fixed degree, that of 212° . This temperature is important in the maceration and infusion of many organic substances, for which, though a greater heat would be highly injurious, the one mentioned is desirable and even necessary. Water-baths are generally constructed with and attached to the vessels in which the heating operation is to be performed: thus, in the carpenter's glue-pot, the vessel containing the glue is inserted in another containing water, the latter being the one placed in direct contact with the fire.

257. A water-bath, besides regulating and equalizing the heat when required near to 212° , may, from the liquidity of the medium used, have its temperature ascertained by a thermometer, and consequently regulated by attention to

* Transactions of the Society of Arts, xli. 70.

the source of heat. Hence it offers the facility of raising substances in closed vessels to any given degree, between 212° and ordinary temperatures: thus if it were required to know at what point a certain wax or a new resin melted, it would only be necessary to put a piece into a thin tube, and the tube with a thermometer, into a water-bath, of which the temperature was gradually raised, and moving the thermometer about to ascertain the temperature of the bath, when just hot enough to retain the substance in a fused state.

258. In the laboratory, the water-baths are generally of extemporary construction. A tin or copper saucepan, shallow or deep, according to the vessel to be heated, makes a very excellent one. The immersed vessel should not touch the bottom of the bath; if it be a flask, or there be two or three to be heated, some hay or straw, or instead of them a little tow, should be placed at the bottom of the bath, and the flask or flasks upon it. A board should be placed across the bath with holes in it to receive the necks of the vessels, and retain them upright and steady; or even straw put loosely into the vessel, or between the flasks, will answer the same purpose, and at the same time prevent any bumping or violent ebullition in the water of the bath. When the vessel to be heated touches the bottom of the bath, heat gains access to it by conduction; the temperature is no longer necessarily the same as the boiling point of the water, and may at times rise so high as to do considerable injury.

259. An evaporating basin frequently answers the purpose of a water-bath, and the substance to be heated may also be placed in a small basin and floated on the water in the first. A glass tube will often form a water-bath for a tube somewhat smaller (918), and frequently when the aqueous vapour would interfere, it is prevented by making the bath-tube the shorter of the two.



260. It is necessary that attention be paid to the quantity of water in the bath, that it may not be so far diminished by evaporation so as to occasion injury or derangement, either by bringing the floating vessel into contact with the

bottom, or leaving parts of the bath itself uncovered. It is often useful for many reasons to put a little oil on the surface of the water in the bath. Suppose, for instance, the source of heat be an Argand lamp (212), or small furnace (158); as the temperature rises, evaporation increases so rapidly, that at last the accession of heat is very slow, notwithstanding the rapidity of combustion, and may, at times, even be limited before it has attained the boiling point, the loss in latent heat being equal to the gain in sensible heat. A film of oil upon the surface prevents the evaporation, and, consequently the loss of heat in this way, and the temperature rises more rapidly, and to a higher degree than when the water is uncovered. If it be required just below 212° , it is easily retained there with a much smaller flame or fire than would otherwise suffice, the water is not liable to diminution, nor will it require watching or renewal, and the quantity of steam given off is comparatively nothing; a point of some importance at times to the substance in the inner vessel. In all cases when heat is required about a certain point below 212° , it is advisable to have a thermometer bulb immersed in the bath.

261. When temperatures above 212° are required in baths, pure water must be dismissed, and either aqueous solutions or metals used. There are several solutions useful for these purposes, which boiling at different temperatures will, of course, communicate heat up to their boiling points. A saturated solution* of

Bitartrate of Potassa, boils at	. . .	214°
Alum	. . .	220
Borax	. . .	222
Common Salt	. . .	224
Tartrate of Potassa	. . .	234
Muriate of Ammonia	. . .	236
Nitre	. . .	238
Rochelle Salt	. . .	240

If a particular temperature be required, 234° for instance, it may be obtained in two ways: either by selecting a solu-

* Quarterly Journal of Science, xviii. 90. Griffiths.

tion which when saturated boils at that point, as one of tartrate of potassa, and then the temperature is regulated by the process of ebullition; or a sufficient quantity of some other salt may be added to the water, so as to form a solution which, though not saturated, will require that or a higher temperature for ebullition, and the exact point may then be regulated by a thermometer. Rochelle salt and nitre are convenient for this purpose, the temperature being carried by them as high as 238° or 240° . The use of oil over these solutions is equally advantageous as in the water-baths (260). Such salts should be selected as have no material action, when in solution, on the vessels used, and are, at the same time, economical and effectual.

262. Solution-baths will produce temperatures up to 360° , but if higher temperatures be desirable, recourse must generally be had to metal-baths. Solution-baths are advantageous for digestions, &c., carried on at temperatures above 212° , and while they possess the useful range of 20 or 30 degrees above that point, they may be prepared with economy in sufficiently large quantities. Metal-baths, on the contrary, are, both from the weight and expense of the material, generally on a small scale, and their principal use consists in subjecting substances in tubes or other vessels to a given or an increasing temperature; or in ascertaining, by the gradual application of heat, which may be measured by a thermometer, at what point any particular effect is produced. For these purposes small baths are as effectual as large ones.

263. Mercury is the substance which first presents itself for these uses: it may be applied, with care, from very low temperatures up to 500° or 600° . If the experiments be made altogether in tubes (259), a temperature of 600° may easily be communicated by means of it; but if the bath be an open vessel, a dish or crucible, for instance, then temperatures higher than 450° should not be given to it; for the metal soon after rises in vapour, and the fumes not only occasion waste of mercury, but, at times, produce injury both to the experiment and the health of the operator.

264. For temperatures from 212° and upwards, fusible

metal answers the purpose admirably. It consists of 8 parts of bismuth, 5 of lead, and 3 of tin, fused together. It melts at a heat below 212° , and will bear a red or even white heat without evolving fumes; but at dull redness, thick films of oxide form on its surface, which increase with its temperature. Tin or lead are both good metals for temperatures above their fusing points; the first melts at 441° , the other at 609° Fahrenheit.

265. These metallic baths may be used in glass tubes at temperatures beneath that at which glass softens (918), or in evaporating basins up to temperatures of 400° or 500° , but only when small. When large, the weight of metal would endanger both the vessel and the experiment. Earthen crucibles are convenient for the immersion of tubes and similarly formed apparatus, but when the mass of metal required is great, an iron crucible or pot, or a small cast-iron saucepan, should for safety be resorted to.

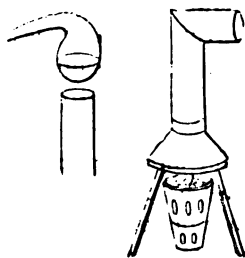
266. A thermometer may be employed to ascertain temperatures as high as 650° , but it should be open above for degrees higher than 580° , as will be stated more fully in the account of that instrument (290). In taking the temperature of the bath the thermometer should be moved in the fluid, for the purposes of equalizing the temperature of the whole by intermixture (286), as much as possible; and, that the tube or immersed body may also acquire an equal temperature with the bath, it should also be moved about. A little tallow or pitch may be put upon the surface of metallic baths not mercurial, at temperatures below 700° , to prevent the surface from oxidizing; but at higher temperatures, the volatilization and decomposition of these bodies would occasion inconvenience. If a bath be hot and covered with a coat of oxide, the latter should be moved on one side with a piece of card or stick, at the moment the subject to be heated is introduced, otherwise a coat may intervene, which will tend to prevent the ready transmission of heat.

267. The operator should always bear in mind when using baths, that the nature of the substance of which the inner vessel, or that containing the body to be heated is composed,

has much influence over the transmission of the heat. It is an obstruction through which the heat has to pass, and the obstruction is the greater, as the conducting power of the substance is less. If the substance be put into a glass tube, and that tube immersed in a water-bath at 212° , it is some time before the contents of the tube will also acquire 212° . If the tube were of metal, its contents would sooner acquire the ultimate temperature, because of the superior conducting power of the latter substance over glass (287).

268. There are occasions, though not of common occurrence, when a bath is wanted that will not permit a rise of temperature so high as 212° . Thus in the preparation of euchlorine from chlorate of potassa and sulphuric acid, it is prudent to heat the tube retort in spirit of wine, or a mixture of alcohol and water; for the temperature not rising so high as with water alone, there is less probability of any accident with this explosive gas.

269. Hot air is an excellent heating agent on many occasions, in consequence of the facility with which it is obtained and conveyed; it therefore claims our present attention. If it be convenient to procure it by any slight alteration about the furnace (169), as for instance, by putting a cast-iron pipe



in one corner, such a source should not be neglected, and will be found constantly useful; but in general it will be more advantageous to obtain it by small fires or lamps, the whole of the gaseous produce of the combustion being employed. A shallow charcoal fire in a small crucible furnace (158) yields an abundant supply of heated gaseous matter. A piece of funnel pipe (165), supported on a tripod over the fire, serves as a channel for the hot stream which may be conducted upwards or thrown right or left by adjusting pieces (169), as may be required: and the temperature of the current itself may be regulated within certain limits by placing the funnel pipe at a greater or smaller distance from the furnace, or having different lengths of it, or increasing and diminishing the fire. Such

a current is useful in making slow distillations or rectifications (439); in heating flasks or globes; in warming electrical machines; and the fire is easily renewed or arranged, and its intensity increased or diminished by opening or closing the holes to the ash-pit without disturbing the apparatus above.

270. Occasionally, an Argand lamp may be substituted for the charcoal fire, when an abundant quantity of hot air may be obtained, by supporting a plate of metal, as a piece of sheet copper a foot square, about an inch above the chimney of the lamp (979). It breaks the current of heated gas and vapours from the chimney, becomes hot itself, and heats the air in contact with it. Such an arrangement is very useful in drying papers placed over it (611), or in warming an electrical machine. Of course every source of combustion for such purposes should yield products free from smoke or fuliginous matter.

271. Steam is in many situations a very convenient agent for the application of heat up to temperatures not exceeding 212° Fahrenheit. If a source of steam, as a neighbouring boiler, be available, nothing more is requisite than to conduct the steam by a small pipe with a stop-cock into a box or vessel containing the substance to be heated. A tin saucepan, for instance, will hold several flasks or two or three retorts, and being closed by a cover, having holes in which to adjust the necks of the vessels, the passage of steam into it, in sufficient abundance, will soon heat them up to 212°.

272. If a steam heat be indispensable for an experiment, and a boiler be not at hand, its place may be readily supplied by a tea-kettle, containing about a pint of water, or even by a tin-can; pipes to convey the steam a few feet, if its pressure be not more than that of the atmosphere, may be readily made of oiled cartridge paper (1337). They should be an inch in diameter, formed of two or three circumvolutions of paper tied round with thread or twine, and placed in an inclined position, that water may not lodge in them. Such pipes should also be surrounded by a loose case, formed by wrapping a sheet of paper round them, so

as to make as it were an external tube, at least half an inch larger than the internal one. This prevents any great loss of heat, and consequent condensation of the steam within them.



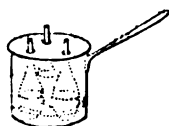
273. Dr. Ure has contrived a very convenient apparatus for the application of heat by steam. It consists of a tin box about eighteen inches long, by twelve broad and six deep. The bottom is hollowed a little by the hammer towards its centre, in which a round hole is cut of five or six inches in diameter. Into this a tin tube three or four inches long is soldered. This tube is made to fit tightly into the mouth of a common tea-kettle, which has a moveable handle. The top of the box has a number of circular holes cut in it of different diameters, into which evaporating capsules of platinum, glass, or porcelain are placed. When the kettle filled with water, and with its nozzle corked, is set on a stove, the vapour playing on the bottom of the capsules, heats them to any required temperature; and being itself continually condensed, it runs back into the kettle to be raised again in ceaseless cohobation. With a shade above to screen the vapour chest from soot, the kettle may be placed over a common fire. The orifices not in use are closed with tin lids. In drying precipitates, the tube of a glass funnel may be corked and placed with its filter directly into the opening of a proper size. For drying red cabbage, violet petals, &c., a tin tray is provided, which fits close to the top of the box within the rim which surrounds it. The round orifices are left open when this tray is applied.



274. A temporary steam bath sometimes readily and advantageously supplies the place of a water bath. Suppose it were required to evaporate a solution at temperatures not higher than 212° , two evaporating basins should be selected nearly of equal size, and putting water into the smaller, it should be placed on the sand bath, or over a lamp or fire, and covered with the larger, into which the solution is to be introduced. The smaller is in this way converted into a chamber contain-

ing water at the bottom, and, when heated, steam at the top; the steam rises, condenses against the bottom of the upper basin, heating it and its contents, and the condensed water returns back to that below. The excess of steam, if there be any, passes out at the side where the lip of the basin leaves a little opening, and at such a distance from the interior of the upper basin, as not to interfere with the concentration of its contents.

275. In other cases the water and steam bath may be usefully combined. The figure represents an arrangement



in which a saucepan is converted into a temporary steam chamber. Three flasks are arranged in it, the necks appearing through holes in a tin plate, which serves as a cover, and which should be dished a little, or depressed in the middle. Water to the depth of an inch or two is to be put into the saucepan, and when the vessel is placed over a little charcoal fire, becomes converted into steam, which rising and coming in contact with the flasks, elevates them and all within the vessel to its own temperature. The water condensed on the under surface of the dished cover trickles back to that at the bottom of the vessel, and by management the flasks are retained for any time at a temperature of 212° , with very little escape of steam or evaporation of the water. This arrangement is frequently more convenient than a water bath made deep enough to receive the whole of the flasks, because of its lightness and the superior steadiness of the flasks, from their not being buoyed up by any quantity of circumambient fluid. A similar arrangement is often useful for distillation or rectification, the body of the retort being introduced into the vessel and heated by the steam which rises from the water beneath.

276. Upon occasions of refined investigation relative to the force of vapours, or the conversion of liquid bodies into vapours below temperatures of 212° , or even as high as 240° , it is useful, for the observation of the immersed apparatus, to have baths of water or solutions, in glass jars or other vessels to which the fire cannot be directly applied,

and which yet require to have their temperatures sustained for a certain period of time. In these cases the end is best obtained by throwing steam into the bath itself, through a tube descending to the bottom of the liquid. Such steam must be obtained from a boiler, because of the pressure of fluid it has to overcome; but small experimental boilers from four to six inches in diameter, that may be placed over a lamp, are sufficient. The tubes must be of metal or glass, not of paper. During the experiment it is well to cover the bath with oil, to prevent loss of heat by evaporation; and also to wrap it round with a dry cloth, or a few folds of paper, when it is not necessary to watch the changes within whilst the temperature is rising. In these cases, two or three thermometers should be introduced into the bath to detect any difference of temperature that may occur at different parts; for where the surface is large, and the cooling agencies powerful, whilst the source of heat is confined to one spot, it is necessary that great care should be taken that all parts of the bath agree in temperature.

§ 4. *Thermometers.*

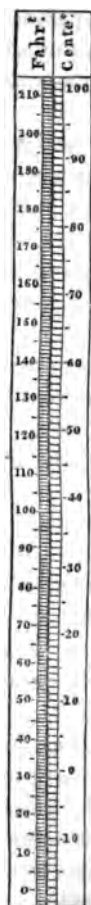
277. The thermometer being an instrument in constant use for ascertaining temperatures within certain limits, it is essential that the student should be made acquainted with the errors to which it is liable, the means of correcting them, and the general circumstances by which its indications are influenced. It will be unnecessary to describe the method of making these instruments, for in consequence of the general diffusion of chemical science, and the practice of chemical arts, they are constructed and circulated in such quantities in commerce, that it is difficult to imagine a place in which such pursuits are likely to be carried on, where they may not be found. Besides, the construction of a thermometer, though simple in theory, is difficult in practice. It requires great tact and dexterity to produce one of very moderate goodness; and without steadily watching the process as performed by another, or previously possessing much practical knowledge in glass-blowing, &c., it would be a vain attempt to make one from a written description. Here,

therefore, we shall confine ourselves to the examination and correction of instruments which are made by others; and this is the more necessary, since ordinary thermometers are frequently inaccurate, sometimes considerably so, and would often lead to gross errors in delicate experiments, though sufficiently correct for common purposes.

278. The most usual thermometer is that which contains mercury, and is sealed hermetically at the top. It should not include air. To ascertain whether it is perfect in this respect, invert it, and by a short sharp shake or two endeavour to make the column of mercury descend in the tube. If but little mercury be in the tube, nearly the whole being contained in the ball, it may be difficult to effect this; it is then facilitated by warming the bulb until a longer column is propelled into the tube, when the shake will generally cause it to descend. As the mercury moves in the tube, it will either leave an equivalent void space in the bulb above, or it will part in the tube itself, a portion only of the column passing downwards. In either case the indication with regard to the presence or absence of air in the tube will be the same, for if the metal traverses the whole length freely and descends to the extremity or nearly so, no air of any consequence can be present. On the contrary, if it passes but a little way down the tube, air is present. If it will not descend at all by any effort that can safely be made, air may be suspected. When air is present, it occasions irregularities in the indications of the instrument, which can only be accurately ascertained by comparing it experimentally with another thermometer known to be correct.

279. Supposing no air to be present, the accuracy of the graduation is next to be ascertained. Thermometers are generally graduated by having two points marked upon their stems, corresponding to the melting temperature of ice and the boiling temperature of pure water in a metallic vessel under the pressure of the atmosphere; and the intervening space is then divided into a certain number of equal parts, each being called a degree. Of these there are 180° in Fahrenheit's scale, and 100° in the centigrade scale. If the scale is to be continued above or below these points, it

is done by making divisions equal in length to the degrees thus ascertained. To try the accuracy of the point marked 32°



Fahrenheit, mix some pulverized ice or snow with a little water, so as to make a thin paste; introduce the bulb of the thermometer into the mixture, and agitate it there for a few minutes until the mercury is stationary on the graduation. If it accords with the point marked 32°, it is so far correct. To try the point 212° Fahrenheit, put some distilled water into a metallic vessel, into which also introduce the bulb of the instrument, holding it near the surface of or in the water; cover the vessel, and make the water boil, so as to yield abundance of steam, the barometer being at the same time at 30 inches, or very nearly so; observe the thermometer after a few minutes, when it has attained its maximum of heat, and if the metal correspond with 212°, that point is also correct.

280. Finally, to ascertain if the intervening degrees are equal, and in that respect likewise correct, separate a portion of the column of mercury in the tube of one, two, or three inches in length from the rest, by inverting and jerking the instrument as before mentioned (278); bring it to different parts of the tube, and consequently of the scale, by inclining the instrument more or less in various directions, and by tapping it if there be occasion; and observe in all these situations whether the portion of mercury so separated occupies the same number of degrees: if it does, the instrument is accurate; if it does not, the degrees are of different value in different parts of the scale, and the instrument is incorrect.

281. Should it be found impossible thus to separate a small part of the column to serve as a test of the scale between 32° and 212°, then the instrument must be compared with one known to be correct, either from its having undergone such trial, or from having been formed from a piece of

glass tube, previously examined with regard to the equality of its bore, by forcing through it a small cylinder of mercury, and thus measured in different parts. If, on comparison, three or four equidistant points prove to be correct, and the scale is found to have divisions of equal length in all its parts, then it may be considered as good.

282. The method of ascertaining whether the scale is equally divided, is to lay it by the side of another scale, an inch rule for instance, and observing how many degrees are equal in extent to a given space on the second scale, then to move it up or down, and examine whether in other parts the same number of degrees are also equal to the same space. The student should understand that ascertaining the points of 32° and 212° , and also the equality in length of the divisions on the scale, is not sufficient to ensure the accuracy of the instrument; since, if the tube be conical or otherwise irregular in the bore, a correct graduation would give degrees unequal instead of equal in length.

283. If neither 32° nor 212° be contained on the scale of the instrument to be examined, then it must be verified by trial with a thermometer known to be correct, and three or four points having been found to accord, the regularity of the divisions must be examined as already described (282). If one of these two important points be included it should be verified as before.

284. If the thermometer to be examined contain alcohol instead of mercury, there is no opportunity of separating a small cylinder of fluid to measure the equality of the division; or of ascertaining the point of 212° in the manner described (279). That of 32° , and three or four others, must then be ascertained as already described (281), and the equality of the scale observed by comparison as before (282).

285. When the scale passes above 212° or below 32° , these parts are examined only by observing that the degrees are equal in bulk to those between the two points. This equality is of course measured by the little cylinder of mercury, as before explained (280).

286. In all experimental comparisons of thermometers,

essential care should be taken that time be allowed them to acquire the temperature of the bath in which they are immersed; and they should be constantly moved about in it, and made to change places, or serious differences may exist between them (266, 267). A large and a small bulb, or a mercury and spirit thermometer, will take different periods to heat and cool, and if observed hastily may not only be examined whilst of different temperatures, but also whilst both differ from the liquid in which they are immersed: treated in this way good thermometers may seem bad, and more harm than benefit will result from the investigation.

287. It is for this reason that trials made by putting a good thermometer and the one to be examined into a hot liquor, and observing whether they sink together as the temperature falls, are often fallacious. If the thermometers be dissimilar in bulk or some other circumstance; if the bath be small, and the time occupied in observing the fall of several degrees be short, the instruments will frequently appear to be a degree or two different, when, if properly examined, they would prove to be alike; and neither of them will indicate, during the process, the temperature of the bath in which they are immersed. It is easy for the student to gain practical proof and experience of the extent of this effect, by taking two thermometers, so far resembling each other, as to indicate alike when immersed in the same bath, and introducing the bulb of one of them into a thin tube with a little mercury in it. Upon immersing that tube in the same bath with the uncovered thermometer, and allowing the heat to gain access to the instrument through the intervening mercury, he will find, on comparing the two instruments, how great a difference will be occasioned between their indications, as the temperature of the bath rises or falls. This effect is due to the thin tube and the mercury it contains, which obstructing the passage of the heat, retard the changes of temperature in the thermometer itself (267). The effect varies with the thickness of the glass, and the quantity of metal, and illustrates sufficiently the differences that may be introduced in hasty experiments,

by the variable thickness of the bulb and quantity of mercury in the thermometers themselves.

288. There are some causes which slightly interfere with the permanency of the indications of a thermometer; but they are of a delicate nature, and need not, except in particular cases, be attended to. It is said that the constant pressure of the atmosphere on the exterior of the bulb, gradually alters its bulk, rendering it smaller, and thus elevating the mercury, and causing it to stand higher in the scale than it ought to do *. It is also said that a thermometer, when cooled or heated considerably, and then returned to its former temperature, does not immediately give the same indication that it did before, but is lower than it should be in the first case, and higher in the second, from the tardiness with which the glass regains its original bulk †. These are refinements which it will not be necessary for the student to consider, until he has advanced so far in the science as to be competent to enter into a consideration of their presumed effects. All that will be necessary is to try the thermometers, should they be old, to ascertain that the graduation corresponds to the height of the mercury, and that they have not suffered a change by time like the first of those referred to. If any opportunity occurs of observing peculiar changes or appearances, it will be proper to note them, for the illustration and explanation of those presumed and delicately influencing causes.

289. It will be unnecessary to describe the peculiarities and uses of all the varieties of thermometers. No other liquids than alcohol and mercury are now used. Ordinary alcohol thermometers must not be employed for the indication of temperature above 180° , for if subjected to higher, they would either yield wrong indications, or burst; but that fluid having never yet been congealed, they may be applied to the indication of exceedingly low temperatures. Mercurial thermometers may be used for temperatures 20° or 30° below 0° or up to 500° or 600° . At these high temperatures

* Bibliothèque Universelle, xx. 117.

† Giornale di Fisica, v. 268. Bib. Universelle, xxi. 254, xxii. 265.

they are very liable to vary from each other in their graduation, for want of an unexceptionable and natural standard point by which they can be corrected.

290. A good mercurial thermometer hermetically sealed, will not indicate temperatures higher than 580° (266), for above that point the mercury boils in the bulb; but when open at the top, and consequently subject to the pressure of the atmosphere, it will indicate temperatures from 60° to 70° higher. If wanted for delicate experiments, these instruments should be small, not merely in the tube, by which the divisions are rendered larger and the indications consequently more minute, but in the bulb also. A thermometer indicates temperature, by taking from or giving to the heat of the body to be examined, until on an equality with it; hence the body changes in temperature upon the introduction of the instrument, and if it be small, whilst the thermometer is large, the heat which results when they are both alike, may be considerably different from that of the body at first. This would cause an important error, which is only to be avoided or rather diminished, by using a thermometer so small that it shall not occasion a material change in the temperature of the substance into which it is introduced. A large thermometer is also longer in heating or cooling than a small one, and may from the lapse of time necessary to allow of its proper change, occasion an alteration of temperature, by allowing the body tried to cool or warm (266). Small thermometers are therefore, frequently more useful and accurate than larger ones; and, in order to compensate for the diminished mass of mercury, whose expansion is actually measured in the instrument, and to prevent the degrees from lessening in length and delicacy with the bulb, the tubes are usually made of a proportionably smaller internal diameter. A great advantage is then gained by using a tube with a flat bore, the capacity being rendered very small, and consequently the degrees comparatively long, whilst the surface to be looked at is large.

291. When a bulb is thin or large and the column of mercury in the tube long, the instrument will occasionally

be affected in its indications by the position in which it is held. Suppose a thermometer having a column of mercury of 15 inches in the tube, to be held perpendicularly, and afterwards inverted, and the bulb held uppermost: if the column did not descend or part in the latter position, there would be occasioned a difference of pressure upon the exterior of the bulb, equal to a whole atmosphere, by this simple change of position; for the column of mercury of 15 inches first exerting a pressure into the bulb, would, in the latter state, be equivalent to an equal pressure added upon its exterior. It is this difference of pressure which, when sufficient to affect the bulk of the glass bulb, causes an apparent difference in the temperature indicated in the two positions. It will therefore be advisable to try the instrument by change of position, to be aware of any effect of this nature to which it may be subject, and which of course will take place, although in a smaller degree, with any departure from the vertical position.

292. Another error, occasionally introduced by a long tube, depends upon the variable quantity of mercury submitted to the heat at the time of graduation and the time of use. If a thermometer, with a tube three or four feet long, be graduated by immersion of its bulb, and two or three inches of stem only, into melting ice and boiling water, and then used in situations where the greater part of the stem, as well as the bulb, is exposed to heat,—the indications may be two or three degrees higher than the temperature to which it is really exposed. A thermometer existed at Whitbread's brewery, some years ago, which belonging to a deep evaporating vessel, passed through the top, and descended perhaps three feet before the bulb entered the fluid; this instrument indicated a heat in the boiling wort beneath, some degrees higher than the same wort brought up in a bucket, and tried by another instrument, or even boiled in a smaller vessel, and yet examined in the usual way, it appeared to be correctly graduated: the difference depended upon the expansion of the mercury in the stem by the heat of the steam above the liquor, to which it was

exposed when in use, which was added to the expansion of that in the ball, the only part heated at the time of graduation.

293. Some thermometers are formed with a chamber or bulb in the upper part, so that if accidentally raised to the boiling point of the fluid within, the fluid and vapour may pass into this space, and the bursting of the instrument be prevented. These are so far advantageous, but they cannot be made free from air, and are in that respect inferior to the others.

294. Thermometers should not be introduced suddenly into hot or cold substances, for then the glass is liable to crack at the stem, and the instrument consequently be destroyed.

295. The graduation of these instruments is sometimes made on the glass, and sometimes on a separate scale. When examined, the eye should be brought perpendicularly to that part of the stem where the mercury stands, so as to look directly through and on each side of the tube, that the correct coincidence of the surface with the scale may be observed. If the graduation be looked at obliquely, through or upon the tube, the apparent places of either the mercury or the degrees are not the real ones.

296. Although accurate graduation has been thus far spoken of, it is with reference only to the mode generally acknowledged and practised, namely, that of ascertaining the freezing and boiling points of water, and dividing the interval into a certain number of equal parts, each of which is called a degree, and used as the model for other degrees, made upwards or downwards on the scale. Whether such a process is strictly philosophical is not the question; all divisions must be arbitrary, and that adopted has the essential quality of producing instruments strictly comparable amongst themselves.

297. Air is a substance, which, though not in general use in the construction of thermometers, is adopted in peculiar trains of experiment; and the student, when engaged in considering the researches of Sir John Leslie and MM. Petit and Dulong, will have occasion to observe the valu-

able uses to which these philosophers have put instruments containing it. The simplest air thermometer consists of a thin glass bulb at the end of a tube, in which is placed a small cylinder of clean mercury. As the bulb changes in temperature, the air within expands and contracts, and has its changes of bulk indicated by the motion of the metal.

298. The great expansion of air by small increments of heat, makes these instruments very delicate, but they are liable to actions and accidents which render them quite unfit to replace mercury and alcohol thermometers. In the first place, the bulk of the air is readily affected by pressure, so that alterations in the barometer cause movements in the mercury without alteration of temperature. For the same reason difference of position causes different indications as the cylinder of metal presses upon, or draws against the air within; causing consequent changes of volume. In the next place, the mercury is liable to change its situation, and to allow air to pass, if the tube be large; and, on the contrary, if the tube be small, the mercury has a tendency to adhere, and will not readily give way before the air pressing on one or the other side of it.

299. When another fluid than mercury is used, the instrument not only remains liable to the effects of pressure, but is subject to other inconveniences; for if the fluid be water, or an evaporable substance, it sends a variable portion of vapour into the globe, according to its temperature, and thus occasions expansion not due to the mere expansion for temperature of the air within; if it be sulphuric acid, it gradually attracts water, and, becoming diluted, is then liable to the same objection; and, if oil be used, it, together with the other fluids, flows within the glass tube, adheres to it, and does not leave it as the mercury does; such adhesion is incompatible with accurate measurement.

300. These instruments can only be used in connection with the barometer. They merely give comparative results, unless indeed their scales be laid down at the time from a mercurial thermometer; and then, from the largeness of the degrees, they serve to indicate very minute changes. When

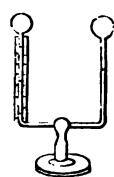
mercury is the substance in the tube, which, by its motion, indicates the change of bulk and consequent alteration of temperature, a few taps given to the instrument will facilitate its change of place. The instrument should always be used in the same position, and if the experiment admits of a horizontal one, it is an advantage, for then the results are not complicated by the pressure of the metal.

301. The air thermometer has had numerous forms given to it, but it will be unnecessary to consider all of them.



Sometimes it is placed with the bulb upwards, and the lower end immersed in a fluid, which, rising and falling within, indicates the change in the volume of the air: some objections are thus avoided, others are originated. Sometimes, in place of dipping into a fluid, the end is turned up, and terminated in a bulb open to the air, and this being partly filled with fluid, a portion of it rises into the tube, and indicates changes in the inclosed air as before. The scales attached to these instruments are usually of a temporary and arbitrary nature; for as, from various causes, the latter differ at different times, they will not admit the application of permanent portions of the scales of other thermometers.

302. The instrument used by Mr. Leslie in his investigations differed in construction from those described, and was by him named the differential thermometer. In this instrument, the aperture, instead of being left open, is attached to a second ball, similar to the first, the tube connecting them being bent twice at right angles, as in the figure, and



the whole closed, so that the indicating fluid within is entirely free from the pressure of the external atmosphere. The fluid used is sulphuric acid, tinged by a little carmine; it yields no vapour to the air in the bulb, and should be in quantity sufficient to fill one of the perpendicular legs and the horizontal part of the tube. When in use, the situation of the fluid is observed whilst both balls are of equal temperature, and then one is subject to the heating or cooling influence, whilst the other is retained unchanged; the motion of the fluid in the tube indicates whether heat or

cold has been occasioned, and, comparatively, to what extent.* The scale is generally arbitrary, but may at any time be compared experimentally with that of a good thermometer.

303. With respect to simple instruments fitted to measure higher degrees of heat than those which can be borne by mercurial thermometers, we are yet deficient; nor does it seem likely that the want will soon be supplied. The student will do well to observe the appearances of a furnace or a substance, as it rises from a dull red heat to the highest possible temperature that can be given to it; to form in his mind a clear idea of the colour and appearance of the light emitted in succession; and to select three or four distinct periods of the ignition to serve him, as it were, for degrees. The terms dull red, red, full red, yellow, white, bluish white, or any others he may choose, should not be quite indefinite, but so far understood and appreciated, and the appearance he intends to express by them so fixed in his mind, that he may be able to say at once whether a fire is above or below any required degree; or, having registered a particular heat by its appearance in his note book, that he may be able to attain it again with considerable accuracy.

304. Daniell's pyrometer is an instrument to measure high temperatures. Its indications result from a difference in the expansion and contraction of a platinum bar, and a tube of black lead ware in which it is contained. These differences are made available by connecting an index with the platinum bar, which traverses a circular scale fixed on to the tube. The degrees marked on the scale, though arbitrary, are in each instrument compared experimentally with those of the mercurial scale, and the ratio marked on the instrument; so that its degrees are readily convertible into those of Fahrenheit. The instrument, after use, will return on cooling to the point from which it set out, and when applied to ascertain a particular temperature, the fusing point of silver, for instance, will give nearly the same indication every time. It is, therefore, much superior to any other

* Leslie's *Experimental Inquiry into the Nature and Propagation of Heat*, p. 9.

that has yet been constructed to measure high temperatures. Mr. Daniell has improved this instrument still farther by separating the scale from the indicating part, so that the latter may be placed wholly in the fire, or even immersed in fused metal. Hence, although not so facile in its use as the common thermometer, which, indeed, is remarkable for its simplicity, yet in the numerous situations where circumstances admit of its application, as in glass-houses, potteries, furnaces of all kinds, &c., it surpasses any other instrument, and furnishes indications of great comparative delicacy.

305. Of late years, thermo-electric indications, founded on Seebeck's beautiful discovery, have been used to tell the temperature of furnaces; but as yet, I believe, the direct application to the determination of the higher temperatures has not been made practical in the hands of an ordinary observer.

SECTION V.

COMMUNITION.

Trituration, Mortars, Granulation, Precipitation.

306. THE division of matter is often highly advantageous in facilitating chemical action, and various processes have been devised for effecting it in the laboratory; some suited to the nature of the substance to be divided, others to the particular state of division required. These processes are both mechanical and chemical; for fusion and solution are more frequently referred to as means of separating the particles of matter one from another, than for any other purpose (356). The latter processes will not be dwelt upon at present; what relates to them, connected with the object of this book, may be arranged more conveniently in other sections, and hence, in this, the references to them will be only

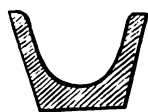
incidental. The operations more immediately in view are those which, while they divide a substance, do not alter its physical state. These of course apply to solid bodies only, and the substance, after the operation, is still in the solid form, however minutely the particles may have been divided. No merely mechanical division can bring a solid body into a state, comparable as to physical properties, with the same body when it has had freedom of motion given to its particles by fusion or solution.

307. Of all the processes adopted in the laboratory for these purposes, none is more extensively useful than that of trituration; chemical operations cannot proceed well without it; nor is any vessel more generally convenient for the purpose than the mortar and pestle, and hence, to meet the quantities and qualities of different substances, several of these vessels, of various sizes and materials, should be included in the laboratory apparatus.

308. In the first place, a large iron mortar, with its pestle of the same material, and of a proper size and weight, should stand on a block in some corner or convenient place in the laboratory (19). It is useful for breaking large lumps into smaller, and for the pulverization of ores, metals, and heavy coarse materials. Two or three mortars formed of earthy materials, and of moderate sizes, from a pint to three pints in capacity, should be provided for table use, and a smaller one for rare substances. Those which are intended to effect the pulverization, and at times the solution of various bodies, ought to possess requisites which it is difficult to find combined. A vessel is required of a material so hard as to bear the blows and friction of other hard bodies for any length of time, without suffering injury or abrasion of its surface; of an uniform and compact texture; not brittle; not permitting the absorption of fluids, or penetration by them; not subject to the action of acids, alkalies, or other solutions; and of a requisite capacity.

309. The difficulty of finding these properties united, has caused the introduction of a variety of mortars for various uses. Those for common occasions are usually of Wedg-

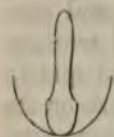
wood's ware, and should admit of the pulverization of most substances, and the preparation of acid, alkaline, and metallic solutions. A mortar of this kind should scarcely allow of being scratched by the edge of a piece of quartz or flint, and absolutely resist steel, not by any glaze on its surface, but on an accidental fracture, as well as other parts. It should not become stained by having a strong acid solution of sulphate of copper or muriate of iron put into it when dry, and left for twenty-four hours, but should allow the salt to be washed off without any difficulty by cold water. On rubbing down an ounce of sharp river or sea sand to fine powder, the sand should acquire no appreciable increase of weight. It should be sufficiently thick at the bottom to resist the blows to which it will at times be subject, as well as to give weight and steadiness. It should not



be of brittle material, and therefore fragile or apt to shiver, though, if unavoidable, that fault is more easily borne with than any other of those mentioned. The proportionate thickness of the vessel in different parts relative to its capacity may be represented by the accompanying woodcut. Mortars of admirable quality are made of Berlin ware (369).

310. The pestles should be of one piece, and of the same material and qualities as the mortar. If in two pieces, as is sometimes the case, the handle being of wood and the bottom only of ware, the cement by which they are fastened occasionally falls out, and produces injury to the materials in the mortar; or by the contraction of the wood, and other causes, a space is formed, which, sometimes receiving and sometimes delivering dirt, may injure an experiment. The pestle should be strong, and its size above, such as may be sufficient to allow of its being grasped firmly in the hand, and below, to permit a considerable grinding surface to come in contact with the mortar. Its diameter, in the lower part, may be about one-third, or one-fourth of the upper diameter of the mortar. The curve at the bottom should be of shorter radius than the curve of the mortar,

that it may not touch the mortar in more than one part, whilst at the same time the interval around may gradually increase, though not too rapidly towards the upper part of the pestle. A mortar and pestle of the relative convexity figured in the margin, may, by inclining the pestle, or bringing it to different parts of the mortar, allow portions of such different curvature to be placed in juxta position, that the intervening space shall increase more or less rapidly from the point of contact, in almost any proportion; a variation which it is of considerable consequence in pulverization to obtain with facility.



311. Neither pestle nor mortar should be quite smooth at the grinding surfaces, or the materials will slip about between them, and not be retained and pulverized. The roughness of unglazed ware is quite sufficient for this purpose. A roughness of this kind is sometimes obtained by use, and is the best that can be produced; but it indicates that the mortar is abraded by the substances rubbed in it, and, if it happens quickly, shows that the vessel is deficient in hardness. When the mortar is such as to wear but little, and is good in other respects, it is then proper to rub a quantity of sharp sand or emery to powder in it, until the required roughness of surface is produced. The operation will be long and laborious, but a good mortar will repay the pains it requires. Besides these mortars, a couple of small ones of the same materials should be procured. They should all of them be lipped, for the convenience of pouring out fluids or fine powders.

312. Excellent porphyry mortars are brought to this country from Sweden; they are very hard, and resist all ordinary chemical action, but they cannot be obtained of large size, and are expensive, from the difficulty of making them out of a solid block. Their forms are variable, being in part dependent upon the pieces out of which they are worked. They should be accompanied with pestles of the same substance.

313. Small mortars and pestles are also made of agate,

and are exceedingly useful for the pulverization and mixture of small portions of matter, which have either been weighed or are scarce. They are generally made more shallow than ordinary mortars, and, in consequence of their form, size, hardness, and closeness of surface, allow of the matter being collected with less risk of loss than from mortars of earthenware. Their hardness is such as to enable them to resist abrasion better than any others. They should not be inconsiderately subjected to blows, being more brittle than the porphyry or ware mortars, and occasionally having numerous and almost imperceptible cracks running through them, which, though so close as not to interfere with their ordinary use, render them weak. If agate mortars be not left roughened within by the workman, it takes a long time by ordinary wear to render them so. It is better, therefore, to effect it in such cases by means of the pestle, and a little emery or sharp sand.

314. Mortars of wood, marble, or iron, are unfit for ordinary laboratory service, because of their softness, and the action of different fluids and substances upon them. A wrought-iron mortar, of from a pint to a quart in capacity, is useful in particular cases, not merely for the pulverization of substances which, not acting upon it, would be too tough or require too many blows for a common mortar, but also as a vessel to contain mercury in its ordinary or in a heated state; it should have an accompanying pestle of iron. Glass mortars are generally unfit for the laboratory, being soft and brittle, and yielding both alkali and lead to particular solvents. Their uses are indeed so confined as to render it wise to exclude them altogether.

315. Let us now consider the operations in which a mortar is available. Most stones may be broken if held lightly in the left hand and struck smartly with a hammer; but when the pieces are reduced beneath a certain size, their inertia does not then afford sufficient resistance. In these and in other cases, the substance, if not too hard, may be broken into smaller pieces very conveniently in a mortar, without loss or dispersion of the fragments. For this purpose it should be placed in the mortar, and struck with the

pestle in successive sharp firm blows, but not too forcibly. If the body be rather tough, as a piece of sal ammoniac, the pestle should be held firmly in the hand, and impelled, not merely by its descending weight, but the force of the arm should be added and continued, until it is stopped by the substance, something like a thrust being given to it as well as a blow. On the contrary, if the substance be brittle, as glass, or many ores, it is better to hold the pestle lightly in the hand, and, having urged it downwards, to let it fall upon the substance with little more than its own force, using it rather as the head of a hammer than in the former manner.

316. If there be any risk of the fragments being thrown about, the mortar should be covered with a flat piece of pasteboard or millboard, having a hole in the middle, through which the pestle may be passed. The fragments broken from the piece pass from under the pestle, and have a general tendency up the sides of the mortar; hence a cover of this kind is quite sufficient to oppose their passage, and retain them within the vessel, notwithstanding the hole in the centre should be considerably too large to be filled by the pestle. For this reason one such cover, in a clean state, will suffice for mortars of different sizes, and should have its assigned place on the walls of the laboratory. When such a cover is not at hand, a clean cloth, with a hole in it for the passage of the pestle, may be used, being drawn by one hand tightly over the mouth of the mortar, whilst the other holds the pestle. This is better than to cover both mortar and pestle with a whole cloth, and to grasp the pestle through it, whilst breaking the body; for then the cloth hangs in folds, is considerably agitated, and frequently catches, and even scatters portions of the substance.

317. If the piece to be broken be too hard for the mortar, whilst large, which is now and then the case, or there be reason to fear injury from it, then it must be either broken in the hand (315), or split or crushed by a hammer on the anvil. When of convenient size, it should, after being laid upon the anvil, be surrounded by the hand, or by the thumb and one, two, or three fingers, according to its size, so that

when struck by the hammer, and split into several pieces, these should not be scattered, but retained together, and afterwards separated by the fingers. The blows should be steady, small at first, and increased in force, until sufficiently powerful. It is not desirable to crush the substance at once, but to break it into large, and afterwards into smaller fragments; and if the body be one which gives way by degrees, the fracture should be effected by successive blows, and not on a sudden. It is desirable that the chemist should, in everything he does, endeavour to obtain a command over the agents he is using; not applying them with such force, or so carelessly, as to render the results accidental. Even in the breaking of a stone, advantage is gained by a cautious mode of procedure, not merely as confirming a good habit, but as most effectually preventing waste, and sometimes in preserving peculiar internal appearances.

318. When the substance requires a blow so hard, that it is unpleasant to expose the hand or fingers to the effects which may happen upon its fracture, it may be wrapped up in one or several folds of strong paper or cloth, and then be struck. If the blow break it, the result will be indicated by the sound, and the feel of the hammer in the hand; if it does not, but at the same time cuts the paper or cloth through, it is not necessary for that reason to change the envelope, but the blow must be repeated upon the same place, until the body does separate. In both cases the fragments will be held together by the envelope, and it is easy to separate them from the wrapper when opened out, by a little motion and friction.

319. Some substances, and especially some of the metals, as cast-iron, copper, alloys of copper, &c., when in mass and cold, can scarcely be broken into smaller pieces on the anvil, except by blows so powerful as to endanger neighbouring bodies, and yet will crack and crumble with facility when heated. In these cases, the substances should be made red hot, and struck in that state, until they are sufficiently cracked, and the separation completed in the vice, either immediately, or after the temperature has fallen.

320. Before leaving this subject of the division of large pieces into smaller, it will be proper to observe that many substances may be separated by nippers or a knife. In these cases it is necessary to attend to the grain of the substance, and take advantage of the greater facility of division which exists in one direction than in another. Muricate of ammonia will separate readily with the grain into pieces without much crumbling. If it is to be pulverized, place it in the mortar with the grain upright, and not horizontal. It may be remarked that there are many substances, which, though too hard to be broken in the mortar when in large masses, without endangering its fracture, or the abrasion of its surface, still may be readily and properly pulverized when in smaller pieces.

321. If the object be to reduce the substance into minute fragments only, of the size of a pea, or pin's head, or smaller, but not to powder; then, having broken it down as before described, the operation is to be continued in the mortar, by a series of blows from the pestle, all grinding action being avoided. The pestle must be held lightly, and allowed to fall sharply on the substance, being directed to those places where the largest pieces are. A slight, lateral, or shaking motion of the hand holding the mortar, between each blow, will help to return the larger pieces from the edge towards the middle of the mass of fragments, where they ought to be when struck, and no blow should be given towards the edge, if it can be avoided; it there only tends to reduce those particles smaller which are small enough, and if a large piece be struck there, its fragments are apt to fly up the sides of the mortar; whereas, if it were in the middle of the substance, they are caught and retained by the surrounding matter.

322. It will be found that a process of this kind, in which all grinding action is avoided, will reduce a substance to small fragments or particles, with the least production of fine powder; and this is highly desirable with some substances which are in a more favourable state for experiment when crushed or broken into small pieces only, than when

more minutely reduced. Flint glass is as convenient a substance as any for the student to practise upon for the acquirement of these methods, and illustration of their effects.

323. In *pulverization* a very different action of the pestle and hand is required. The object then is to reduce the whole of the substance into fine particles as rapidly as possible. The process of striking or stamping would now be found too slow; a grinding action is necessary to expedite the operation, and this it will be proper to adopt as soon as possible. Even, therefore, whilst breaking down the larger lumps into smaller, it will be desirable to alter the character of the blow; and instead of holding the pestle lightly in the hand, and letting it almost drop on to the middle of the substance, it should be grasped firmly, and forced down by the muscles of the wrist and arm, pressure being added to the blow; and it should be made to fall on the substance at the side of the mortar, the pressure being continued till the pestle has reached the middle. The blow is to be oblique in its direction, going down the side of the mortar to the centre. It is best given on the part farthest from the operator, more force being then exerted, as it is continued by a downward pressure to the middle of the mortar. This kind of stroke breaks the larger fragments, grinds both these and the smaller, and mixes and alters the position of the whole; and, if continued in the same direction whilst the mortar is turned a little way round by the other hand between each stroke, every part of the substance is brought in succession under its comminuting action.

324. The substance is thus soon reduced to particles so small that the pressure of the hand is sufficient to continue the division without the force of a blow. After this it is most expeditious to advance the operation by rubbing. For this purpose, the pestle being grasped firmly, should be moved in larger or smaller circles around the centre of the bottom, at the same time pressing hard and regularly upon it. It is in vain to expect a rapid effect in this operation without pressure, or to give pressure without labour, but certainly much labour is exerted in vain by those who give

an unequal and uncertain pressure. The motion of the pestle should be in circles, commencing at the centre, and gradually expanding outwards: this, whilst it grinds the substance, gradually displaces it, turns it over, and mixes it. When it has arrived at the exterior of the mass, the circles described should gradually be contracted, until they have again closed in the middle, when they should re-expand, and thus the operation be continued until the powder be sufficiently fine. The process is least fatiguing to the hand when the circles are up the side of the mortar, towards the limits of the substance, and the grinding proceeds most rapidly there. By making a smaller circle now and then, it is easy to urge the fragments outwards in that direction, so as to take advantage of the most favourable circumstances. Occasionally, deviations from this regularity may be convenient, for the purpose of moving the substance in different directions; but it will be found that the more nearly they are adhered to, the more rapid will be the operation.

325. The pestle may be held in both hands in succession, for the relief of the wrists; but the hand not occupied by it should take charge of the mortar, and, holding it firmly and steadily, should sometimes turn it a little way round, especially if the force of the hand holding the pestle be unequal in different parts of the circle. The motion of the pestle may be either in one direction or the other, and an inversion of it is now and then advantageous for the more effectual mixture of the particles. During the whole process it should be observed that every part of the powder is rubbed, and the tendency should be to grind those parts first which appear coarsest, and not to finish one portion before another.

326. The opportunity already referred to of obtaining different inclinations between the surface of the pestle and that of the mortar (310), by either inclining the pestle or carrying it to different parts of the mortar, may now be taken advantage of. At the commencement of the operation, for instance, whilst the particles are coarse, it will be proper to incline the pestle so that the preceding part of its grinding surface may pass over them; by which they

are included between it and the mortar, and are crushed by the following part. Particles are thus instantly broken down, which, if the pestle were held upright, or if inclined in a wrong direction, would merely be pushed forward. In the same way, even when the powder is of considerable fineness, the pestle may be made to have more of a mixing or a grinding effect, according as it is inclined one way or the other—both being peculiarly desirable at times. Many other advantages of this kind are attainable, which are, however, better learnt by practice than from description, which would necessarily be very minute and tedious, and at the same time very imperfect.

327. The student should be aware also of the peculiar uses of the different parts of the inner surface of the mortar. The powder lies quietly at the bottom of the mortar; on the sides, a little way from the centre, it also rests with facility, but with a tendency to pass to the middle as the pestle moves over it; farther outwards it arrives at a part so inclined, that, when forced upwards as the pestle passes, it falls back again when left at liberty; here, consequently, a mixing agency may be exerted, whilst the operation of grinding goes on more effectually at a part nearer the centre, not merely because the powder rests there and awaits the approach of the pestle, but also because, from its being nearer to a horizontal position, the hand has more command over the pestle, and power in pressing it down.

328. The quantity of a substance put into the mortar at once should bear a proportion to its particular qualities and to the ultimate state of fineness required. If the substance is to be finely pulverized, only small quantities should be operated on at once, so as to form but a thin layer at the bottom in those places which the pestle has passed, and to insure the subjection of the whole to trituration. If the layer under the pestle be thick, a grain may be imbedded in it, and remain uncrushed by the pressure. If the substance be in great quantity, a particle may be pushed about from side to side, enveloped in the mass, and without coming under the pestle at all; and what may happen to one particle may happen to many, and thus the powder be a mix-

ture of coarse and fine. For coarse powders larger quantities may be taken. Hence, also, when a lump is to be broken down into a fine powder, it is frequently better to reduce it to a coarse powder, and then, removing it from the mortar, to return it in small portions, each of which is to be brought to the state of fine powder by itself.

329. A soft or readily pulverizable body may be put into the mortar in larger quantities than a hard one; thus a large quantity of chalk may easily be reduced to a fine powder at once, whereas, if as much siliceous sand were operated upon, the attempts to reduce it to a powder as fine would fail, or be interminable. It is easy to understand that any substance, whose particles are so hard as to require direct pressure between the mortar and pestle, is in too great a quantity when there is so much present as to prevent the approach, almost to contact, of the two grinding surfaces.

330. The state of fineness to which a powder has been reduced is judged of principally by the appearance. If the body be coloured, the colour becomes paler as the powder is finer, and generally at last almost disappears. When the powder, in place of flowing freely down the sides of the mortar, begins to adhere and clot as it were, it is also a mark of considerable division; and when it is in such a state that, previously dry and granular, it now seems almost moist, and, being moved about by a spatula, preserves the form given to it even when the lateral surfaces are perpendicular, it is then in an extreme state of division. This indication must, of course, be considered in connection with the hygrometric powers of the body. The student may observe all these appearances by operating upon a few fragments of bottle glass (not flint glass, for then some fallacies are introduced), or a few pieces of calcined flint.

331. Passing from this general consideration of the process of pulverization, it may be observed that particular bodies require slight variations in the process for particular purposes. If the substance be poisonous, or if it be in exceedingly fine powder, and liable to dispersion from the motion of the air, it may advantageously be moistened with

a little water, provided that fluid has no action upon it; but the trituration is then more laborious, from the greater difficulty of mixture and the adhesion of the substance: it is, however, a precaution continually adopted with substances subjected to the grinding-mill. When the pulverization is finished, the substance may be dried, if that be necessary, or, if not, left in the state in which it comes from the mortar. At other times, to confine the powder, the mortar may be closed up by a cover, a millboard, or a cloth, as described in the directions for breaking down substances (315); but the aperture should now be as small as possible, or the finer particles will escape by it.

332. When the substance to be pulverized is stony and hard, advantage is frequently gained by igniting the mass, and quenching it in water. Flints, many siliceous and other hard stones, are thus rendered more brittle and divisible, and their comminution considerably facilitated. Charcoal is a substance which is found to pulverize with far greater ease and rapidity when hot, or after being recently heated, than when cold; ignite it therefore, and in this state introduce it into the mortar, and instantly rub it to powder. Camphor, which has a toughness under the pestle, is easily reduced to powder when moistened with a few drops of alcohol. Gum, when pulverized, should be kept perfectly dry. Zinc may be reduced to powder when hot, in a heated iron mortar, the pestle also being heated.

333. Shell-lac, some resins, and other substances, when divided for the purpose of facilitating solution, are better in small fragments than in fine powder. Adhesive organic substances, which would knead together under the pestle, are frequently rendered capable of division in the mortar, by being mixed with clean sand or glass; such substances being chosen in these cases as will be inert with respect to the agents to which the bodies are to be subjected.

334. The transference of materials to and from the mortar, and generally of substances in powder or small grains, is most conveniently effected by the use of spatulas, or similar instruments. Common broad bone paper-knives make excellent spatulas for the laboratory, for this and other

uses, and may be used to disturb or separate the substance when it adheres together in the mortar, or to the sides of the vessel; but the precaution must be taken of not using them in those cases where they may affect or be affected by the substance, or where, from its strong adhesion to the mortar, the removal may cause such abrasion from the spatulas as to communicate so much matter as to be injurious to the experiment. In these cases the platinum spatula, before referred to in weighing (62), is to be used, and hence a reason for the degree of thickness and strength already recommended.

335. When the substance to be pulverized is coarse, and its quantity unimportant, a piece of pasteboard or a card is very useful in supplying the place of the spatula, in clearing the substance from the mortar; it at times even surpasses it in effect and convenience, from its pliability and consequent adaptation in form to the mortar, and also from the larger quantity which it will lift at once. Some waste cards should always be ready, in one of the laboratory-drawers, for these and similar uses.

336. Where a hard substance is to be pulverized for the purpose of delicate analysis, it is sometimes necessary to take into account the matter which may be removed from the mortar during the process, and estimate its influence in increasing the quantity of products ultimately obtained. In such cases a mortar of known composition should be used, one of agate for instance, where the substance removed may be assumed to be silica, and thus the correction made at the proper time, by subtracting so much weight from the silica evolved in the analysis.

337. It is highly important that the pupil should be aware of the hygrometric power of many substances, which, when they are reduced to powder, is so greatly developed by the enlargement of surface, as very seriously to increase the whole weight of the substance. M. Pajot Descharmes says, that he has had an increase in the weight of rock crystal by mere pulverization to such an extent, that the original weight was doubled.*

* *Recueil Industriel*, vii. 64. *Quart. Journ.*, New Series, iv. 425.

338. The diamond is most conveniently pulverized in a steel mortar, having a cylindrical chamber; the pestle is replaced by a steel cylinder of such size as to pass easily into the cavity. The diamonds are first introduced, and afterwards the cylinder; and the latter being struck with a hammer, the gems are crushed and reduced to powder of any degree of fineness required, without the risk of dispersion. When first used, a portion of diamond is lost, as it were, by adhesion to the steel surface: this should be left, because it prevents a similar loss at a second or third operation. Such a mortar should be reserved exclusively for the pulverization of these gems; for, besides avoiding a repetition of the loss already referred to, it would be laborious and difficult to clean the instrument so completely from diamond, that if sapphires, for instance, were afterwards pulverized in it, a portion of diamond should not be mixed with the produce.

339. In analysis and other operations, a given weight of a substance in powder, as 100 or 200 grains, is often required. This quantity should not be first weighed out, and then pulverized, because probably a little loss would occur during the operation from adhesion to the mortar and to the transferring tools; but more than the weight required should be reduced to powder, and when in a proper state, the exact quantity should be weighed out.

340. Pulverization is sometimes useful, not for the purpose of accelerating chemical action, but on other accounts. When substances are to be heated which decrepitate in the fire, by which portions may be dispersed and lost, the effect is prevented by previous pulverization. Decrepitation is generally occasioned by the expansion of the outer portions before the interior has had time to heat, and in that respect resembles the breaking of a glass vessel by a sudden increase of temperature. By comminuting the substance, this difference in different parts of the same mass is avoided, and the body sustains the heat without disturbance. If the substance be liable to a similar effect from included moisture, pulverization, by opening passages for the vapour, is equally effectual in preventing it.

341. Pulverization is sometimes effected by grinding the body under a muller, upon a flat stone; but the process, though useful in some of the arts, especially where the substance is to be mixed with fluid into a paste, is so inferior to the use of the mortar, in the laboratory, that it will be unnecessary to describe it here.

342. It seldom happens, perhaps never, that the operations of pulverization reduce the body into a powder consisting of particles of equal size; and in by far the greater number of cases, the difference between them is evident. This, though of no consequence on some occasions, renders it necessary on others to separate the mixture of differently-sized particles into portions containing such as more nearly resemble each other in magnitude. The ordinary and well-known operation of sifting is so simple as to require no notice here, except to point out the use of two or three sieves in the laboratory, which, if used for different substances, should be cleaned after every operation, either by a brush, or, which is better, by passing a stream of water through them.

343. The sieve may also be had recourse to as an excellent means for effecting the mixture of powders, provided the particles are of such size as to pass very freely through it. Two or more such powders, first mingled by the hand, or a spatula, and then passed twice or thrice through a sieve, will be very uniformly mixed.

344. Another mode of separation, in very frequent use, is that of washing; for as light and minute particles are suspended in a fluid, whilst the larger and heavier descend, it thus affords a ready mode of separating them. This operation can be applied to few bodies except such as are insoluble in water, that being the fluid almost constantly made use of. It may often be conveniently effected in the mortar in which the pulverization itself is carried on. Suppose a stone were to be reduced to powder, no particle of which should be beneath a certain degree of fineness: the stone should be pulverized in the mortar in the usual manner, and when, from the appearance, it is concluded that a considerable quantity of fine powder is produced, two-thirds

of the mortar should be filled with water, and the powder mixed well up in it; being now allowed to stand a very short time, until the particles which are considered as too coarse have descended to the bottom, the supernatant mixture should be poured off into a large basin or jar, leaving the heavy powder only in the mortar, with a little water. Then, without adding more water, or endeavouring to remove that which is still present, the pestle is to be used again, until, from the ready mixture of the substance with the water, and the production of a smooth soft paste, it is assumed that much more of it has been reduced to fine powder. Water is to be added to wash this off as before, the finer part being joined to the first portion separated; and the operator is again to proceed with the comminution of the residuum until it has in this manner been entirely removed from the mortar.

345. If by this process the powder be sufficiently reduced, and a greater regularity as to size amongst its particles be not required, then the mixture of it with water should be left quiescent until the liquid be clear, and the powder in mass form a stratum beneath. The former should then be poured off, and the latter dried; and if during desiccation it adheres and produces soft lumps, these are easily broken down in the mortar.

346. If, on the contrary, more uniformity in the powder be required than is thus obtained by a first set of operations, it may be effected by a second, and this will often be necessary when the substance pulverized is such that a very short period only can be allowed for the deposition of the larger particles; for the motion of the water not having subsided, and being unequal in different parts, some large particles will pass over with the finer. In such cases a return of the matter to the mortar, and a repetition of the washing, will frequently separate much of the substance that requires further trituration. This second washing need not be deferred till the whole has settled from the water of the first washing; but all being stirred together, and allowed to stand for rather a longer period than before, the suspended

portion may then be poured off, and the rest operated with as directed (344).

The longer the period allowed for subsidence, so much the finer will be the particles still remaining in suspension, and hence an easy process for obtaining the substance in powder divided to any degree required.

347. Another method of washing is to use a small mortar, and, after having powdered the dry substance in the usual way, to place the vessel in a large strong dish, and then, directing a small stream of water into it, to continue trituration in a steady, slow manner. The water, after filling the mortar, will flow over into the basin, carrying the smaller particles with it; and as the trituration proceeds, the current will continually separate the finer part, until the whole has passed from the mortar into the dish. The fineness of the particles washed over is regulated by the depth of the mortar, the size and force of the current, and the degree of agitation given by the pestle in grinding. To insure a powder of considerable uniformity, the operation should be repeated as before described (346).

348. The same principles and processes may be applied to the separation of insoluble substances of different specific gravities. If an ore contain metallic silver diffused through an earthy matrix, the processes of pulverization and washing will almost entirely separate the earths from the metal. Or if platina ore be treated in the same way, a separation of the iridium and osmium, and other substances, from the grains of metal, may in this simple manner be effected to a great extent, and the platina very much cleansed.

349. It is rarely that any other washing agent than water is had recourse to; but in peculiar cases, and for small quantities of matter, oil may be used. From its tenacity it requires a longer portion of time before deposition takes place, and the division may consequently be more accurately effected. It may be burnt off so as to be entirely removed from the powder, provided the latter be of such a nature as not to be affected by the single or joint action of oil and heat.

350. If silica be required in a state of extreme division, it may be obtained by mixing (343) one part by weight of finely pulverized flint glass, with two parts of pulverized white marble, heating the mixture to bright redness for half an hour, rubbing it in the mortar and again heating it; then acting upon it in an evaporating dish (369) by muriatic acid added till in slight excess evaporating to dryness (594), and re-dissolving in warm water with a little muriatic acid. The insoluble portion is to be well washed in abundance of pure water, until free from salts of lime or lead, and being then dried, the silica will be in a state of division far surpassing any which can be obtained merely by mechanical means. The alkalies cannot be used in place of lime or its carbonate for this purpose, for portions of them remain combined with the silica.

351. Of the metals, all that are brittle may be pulverized. The division of zinc in this way when hot has been before mentioned (332). Some metals may be obtained in a useful state of division by granulation. This is particularly the case with zinc, copper, tin, and lead. For this purpose, the metal is to be melted in a crucible, and then poured from a height of two, three, or four feet, into a pail or pan, full of water: a considerable depth of water should be allowed, as the slight explosions, which sometimes happen, are then less likely to take place. If the water be hot, the pieces become filmy, and blown up as it were into bubbles; if cold, they have more solidity, are smaller, and approach nearer in their form to shot, differences which are dependant also in part on the temperature of the metal itself. The crucible should be moved during the time the metal is running from it, that the descending stream may continually change its place in the water.

352. Some metals are brought, by lamination, into a state equally advantageous for chemical action from the extent of surface exposed, as that produced by pulverization; and the process is applicable in cases when the latter cannot be resorted to. Thus platinum, tin, lead, zinc, copper, gold, and silver, are obtained in the state of foil; platinum, gold, and silver, in the state of leaf; and are highly

advantageous in certain experiments, when thus attenuated. The chemical action which takes place between platina and tin is in no way so effectually exerted, or so advantageously shewn, as when pieces of each metal in the state of foil are laid together, folded up into a ball, and heated red hot. They combine in that case with such force as to produce vivid combustion.

353. The same advantage, dependant upon extension, is obtained to a considerable degree by drawing the ductile and tenacious metals into wire, their state being then for many purposes equivalent to that of actual division. Pure iron, which would resist the processes already described, is successfully attenuated in this way.

354. At other times the tough and ductile metals, as well as some others, may be divided by the action of the file. In such cases the files should be very clean. If new, attention should be paid to the oil with which they are in that state generally covered. If they have been used, the absence of dirt, metals, or other substances, from between the teeth, should be ascertained and secured, and the clean state of the surface upon which the filings are to fall should not be forgotten. Iron and zinc are most generally required in the state of filings.

355. Occasionally metals may be divided into small particles by being fused, and then poured into a wooden box and well shaken until solid and much cooled. Zinc, lead, tin, antimony, &c., may be so pulverized, but usually a part of the charred wood is mixed with the metal, and the surface of the particles is generally oxidized. This method should be used only when no other is applicable or attainable.

356. Silver, copper, gold, platina, and lead, may be usefully divided by chemical means—silver, by introducing a plate of copper into a solution of acid nitrate of silver, until about one-half or three-fourths are precipitated, the metal not being allowed to accumulate upon the copper, but shaken off from time to time, and at last (removing the copper plate and solution) washed with distilled water until tasteless, and then dried. Copper may be prepared in the

same manner by immersion of a plate of iron in a solution of sulphate of copper with a little sulphuric acid added to it, and should afterwards be washed with dilute sulphuric acid, then with water, and finally dried. Gold may be prepared in very fine powder by adding a solution of proto-sulphate of iron to one of muriate of gold, and then washing with a little muriatic acid and pure water. Platina is procured in a state of extreme division, though the particles adhere slightly together, by heating the ammonio-muriate of platina to dull redness in a crucible, until fumes cease to rise. It has the appearance of a sponge, though perfectly metallic. By heating the tartrate of lead in a close vessel or a tube to dull redness, a mixture of charcoal and lead is obtained, in which the latter is in such an extreme state of division, that on exposure to the air it takes fire. It is the pyrophorus of Dr. Gobel, and seems to owe its property only to the state of division of the metal; the action of oxygen, which in general is merely sufficient to tarnish the surface of lead, being here, from the comparative absence of all solidity, and the existence of surface to an almost infinite extent, so simultaneously exerted upon every particle as to cause ignition,

357. Organic substances, which are not sufficiently brittle to admit of pulverization, such as wood, horn, &c., may be cut, or crushed, or rasped, or grated, according to circumstances; a division sometimes gross, sometimes minute, being required.

SECTION VI.

SOLUTION, INFUSION, DIGESTION, &c.

358. THERE are two great and general objects to be gained by solution, which render it a process of constant occurrence in the laboratory. The first is that of preparing substances for the exertion of chemical action; and from the perfect

manner in which it separates the particles one from another, every obstacle dependant upon the attraction of aggregation is removed, at the same time that other advantages are obtained (306): the second object is that of separating one substance from another; this being continually effected by the use of such fluids as have a solvent power over one or more of the substances present.

359. These great uses of solution render it proper to shew the means by which to effect and facilitate it; in what manner to select the vessels and solvents; and to point out any peculiar circumstances or conditions attending it, which may assist the process. But it will be right to premise that the solution here to be considered relates almost always to solid matter, sometimes to liquid matter, but not at all to gaseous substances; for any processes or directions for the solution of gases in liquids will be more intelligibly and instructively considered in the section on gaseous manipulation. Indeed the processes requisite are so different to what are here to be described, as of themselves to suggest the propriety of the separation. The course of this section will be generally from inorganic to organic substances; for in that way the simplest instances and methods will come first into view.

360. It may be remarked at the outset, that solution is of two kinds, being effected either by fluids which have no chemical action upon the substances to be dissolved, or by others which have such an action; both are of constant use in the laboratory. For where, as very often happens, solvents of the first kind fail, recourse must be had to the latter, and then much care and judgment is required in the selection of those which will best effect the desired end. Attempts have been made to distinguish between these two methods, by the use of the terms *Solution* and *Dissolution*, but they have been partial and imperfect, and chemical works now constantly speak of solution of the metals, of earths, &c., and, therefore, virtually reject the distinction.

361. Water is the great solvent whose aid is first to be called in; others are to be resorted to only when that is insufficient. So general and important is its use, that in

speaking simply of the solubility of a body, water is always understood to be referred to. All aqueous solutions of solid bodies are heavier than water; upon this difference is founded a very convenient indication of solubility, frequently useful, always easy. It is to suspend a piece of the substance in a glass of clear undisturbed water; if the body be soluble, a descending current will be seen to fall from it, and be visible upon looking through the water horizontally. If it fall rapidly and in dense striæ, it will indicate rapid solubility, and the formation of a dense solution; if it fall in a very narrow stream, it will indicate only moderate or slight solubility; and by its descending rapidly or in a slow broad stream, or by resting about the substance, a judgment may be made of the comparative density of the solution produced. If no descending current appear, nor any fluid round the substance of a refractive power or colour different to that of the water, then the body must be very nearly if not quite insoluble at common temperatures.

362. Another indication of solubility is gained from the taste. The saliva in the mouth is, as to mere solubility, nearly the same as water, and, generally speaking, those substances which are most sapid are most soluble. The impression of taste in the mouth is, however, frequently a mixed sensation, being dependant in part upon the olfactory nerves; and consequently odorous bodies will frequently appear to be highly sapid, when they are not so upon the tongue.* This is the case with camphor, which, if taken into the mouth after the nostrils have been perfectly closed by the fingers, so that no air can pass through them, will seem to have little or no taste; whereas, the moment the fingers are removed, and the aroma has access to the olfactory nerves, an intense taste, using the word in its ordinary acceptation, is perceived. A similar effect may be observed with a peppermint lozenge or a piece of chocolate. Still, however, the indication may in many cases be useful, and has the advantage of requiring no apparatus, and being easy of performance.

* Chevreul, *Mémoires du Musée*, x. 439.

363. If the substance appear to be insoluble, or if it be necessary to know whether it be soluble in alcohol, ether, oils, or any other body, for the purpose of selecting a solvent from among them, a portion should be pulverized finely, and introduced into a small tube, with a little of the fluid to be tried, and heated; if the substance disappear, it is of course soluble. But if it be supposed to be a mixed body, and partly soluble, though not altogether so, then the presumed solution should be poured from the tube into an earthenware or platina capsule, and evaporated carefully and slowly; if any substance remain, it of course indicates solubility. Trials by evaporation cannot be made with oil unless the body be fixed and will allow the oil to be burned off; nor can trials of very volatile bodies be made in this manner. It is almost needless to add, that cases may occur requiring much chemical skill and judgment; and that it would be impossible to give directions for every possible occasion.

364. Indications of solution dependant upon chemical action are obtained from the changed appearance of the substance. A body not soluble in water except by the use of acids or alkalies is generally, though not always, rendered so by chemical action, and has its properties changed. It is rarely that these chemical agents are applied with any other liquid than water. Indications of their power may be obtained in the manner before directed.

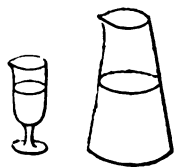
365. With regard to the solution of one liquid in another, no difficulty will occur in ascertaining whether it takes place or not. A small portion of the most valuable should be put into a tube, and then a very little of the other added to it; agitation, followed by rest, will shew whether the two have permanently mixed, or whether they separate again. If the latter be the case, let further portions of the second liquid be added, agitating and observing as before; and this should be done until the whole becomes one clear fluid, or until the volume is increased to many times its former bulk. A conclusion, according to the state of things, must then be made.

366. It may here be proper to warn the student of an

appearance which sometimes takes place during mere solution, which has been frequently misconstrued into an indication of chemical action. Common salt, and several other salts, as well as their strong solutions, and also alcohol or spirit added to common or even distilled water, which has been exposed to air, frequently causes the evolution of a number of small air bubbles; these have the appearance of being the direct result of some chemical action, but are occasioned merely by the expulsion of the air dissolved in the water, which being incompatible with the substances added, is separated. Some of those solutions which dissolve air produce the same appearances when added to the bodies mentioned.

367. Whenever a dissolving power exists at common temperatures, it is generally heightened, and sometimes to a great degree, by an elevation of temperature. There are only three known cases in which heat diminishes the effect: these occur with lime, magnesia, and sulphate of soda. But there is, I believe, no instance of a body not soluble at common temperatures being rendered so by the mere application of heat: it is the quantity of effect only, and not its existence, that is thus influenced. The change is, nevertheless, very important, as favouring and facilitating the desired object; and comminution is also of great value preparatory to solution, for the same reason.

368. The vessels required in the laboratory for the purposes of solution are numerous. They should be competent to resist the action of heat, acids, alkalies, all aqueous solutions, and, for convenience, should as often as possible be transparent.



Hence the necessity of a dozen or two of glasses; they should always be lipped, and ale glasses will answer the purpose very well. Glass jars will also be required, and are best of the form depicted in the wood cut (505), as they then answer other purposes, to be referred to in Section VIII. They should be from one to two or three pints in capacity.

369. Lipped earthenware basins, from $1\frac{1}{2}$ to 10 inches in diameter, are also necessary. They should be tried by a

solution of muriate of iron, or sulphate of copper, both on the glazed and unglazed part, in the manner directed with respect to mortars (309), for which purpose a little of the solution should be put into one basin, a smaller basin dipped into it, and heat applied. A strong solution of sulphate of indigo and an infusion of logwood are also good agents to try them with. The basins should be quite dry when put into them, and after being boiled in the colouring fluid, should be immediately washed clean in water. Basins which will stand a trial of this kind are in that respect excellent. Those which are manufactured at Berlin are admirable in these respects, and may now be obtained in London,* with other important articles, as tubes, crucibles, mortars, &c., of the same manufacture.

370. If such as these cannot be obtained, those of less excellent quality must suffice. Of whatever kind they be, they should resist the action of acids and alkalies in solution. They should also be chosen thin rather than stout and thick, though some of both are desirable; but when intended to sustain the application of heat, the thinner they are the better, so that they have sufficient strength to bear safely the utmost weight of fluid they can contain. Chemically considered, it is desirable that they should be made thin at the bottom, and thicker at the sides; they then sustain the sudden application of heat much better than if thick at the bottom. Their greater liability to mechanical injury must be guarded against by increased care.

371. A dish or two made of pure silver, and a few platina capsules, are also necessary. They should have a projecting tongue of metal to serve as a handle by which they may be held with a pair of pincers. The silver dishes may be as large as can be permitted up to six inches in diameter. The platina capsules should be about $1\frac{1}{2}$ or 2 inches in diameter. Very useful glass dishes and capsules are made out of old retorts, receivers, and flasks, in the manner to be described hereafter (1211); and they will admit of the application of heat carefully applied. It is not advantageous

* Newman, Regent-street; Knight, Foster-lane; and other places.

to purchase glass dishes for the preparation of solutions; they are so brittle and liable to fracture from heat, as to be both expensive and dangerous to the experimenter's results.

372. Flasks are very useful. Those made of flint glass should vary from an ounce to a quart in capacity; the neck should expand at the mouth, or a projecting ring should be formed on it, that the flask may be held safely by that part without danger of slipping. They should be ex-



amined with respect to thickness, and the most uniform should be chosen, provided they be not so thick as to be liable to rupture by heat, or so thin as to burst by the weight of the fluid, or by handling when filled. The thinnest that are of sufficient strength should be selected. The bottoms should be particularly observed: they are frequently much thicker than the other parts, and then almost invariably break when placed upon the sand bath or over a lamp. The thickness of a flint-glass flask from half a pint downwards in size, should be about that of an ordinary Florence flask: when larger they should be somewhat thicker. The indications by which irregular or excessive thickness is judged of are dependant upon peculiar appearances of the reflection and refraction of light, and are best learned from an ocular examination of a good and of a decidedly bad flask. They may now be had with the bottoms pressed upwards, so as to stand well on tables without supporting rings.

373. Florence flasks are very useful vessels, and for most purposes are superior to flint-glass flasks. They are always thin, and require careful handling when filled with a fluid, or they will be crushed from the attempt to support the weight. If resting upon the bottom, they should be supported by a large surface (68). It is seldom that they are knotty, but should that be the case, the flask ought not to be subjected to the action of heat, lest it should fly. Liquids should never be put into a cracked flask or glass vessel, for the purpose of being heated. Florence flasks may be obtained of two sizes, by application to oilmen, or

to foreign wine-merchants; the pints having been used to contain olive oil, the quarts to hold wine.

374. Besides these vessels, stirrers are frequently required in the progress of these operations. They should be made of solid glass rod, and not of tube. The diameter may vary from the quarter to the one-third of an inch; the length from six to ten inches. After being cut off from the glass rod, the ends should have the sharp edge round them removed by a fine, or a dull file; or they should be softened in the blow-pipe flame (1154), and in that case some should be left round at the extremities, and others conical, each having its particular uses (70). Mr. Phillips bends them very slightly in the blow-pipe flame, which prevents their rolling off the table. Enamel rod is sometimes used for this purpose, but glass is harder and not so brittle. Thick glass tube is not good, because the sealed end is apt to crack off in hot solutions, and then the cavity opened is a receptacle for dirt. A bundle of cut straws from the straw bonnet makers supplies excellent stirrers for many common purposes, each straw being used but once. All these utensils are equally useful for evaporation and other processes, as for solutions, requiring in these cases generally no other qualities than those before mentioned. This being understood, they will not be referred to again.

375. Proceeding now to the operations of solution, the following method is very ready, and of constant use in the laboratory relative to salts and similar substances, which are entirely soluble, and form a solution of sufficient strength without the application of heat. The substance should be put into a clean mortar, a little water be added, and by the action of the pestle the solid matter reduced to a thin paste; this is done in a few moments, more water should then be added, and the whole stirred together, in consequence of which the finest particles will rapidly disappear. When upon continuing the trituration, the fresh portion of small powder which is produced does not seem to dissolve, the whole should be allowed to stand a moment, the fluid poured into a glass or jar, the residuum trituated, water added, and the process continued until the whole is

dissolved. The solution when all together should stand a few minutes, to deposit any minute particles that may not have been dissolved; or a little water added to it, and the whole agitated, when it will immediately become clear or nearly so. If there be occasion it should then be filtered, and in this way a solution nearly saturated, and always strong enough for ordinary laboratory uses, may be made in a few minutes.

376. This method of facilitating solution by mechanical division is very useful in numerous cases. If one substance be embarrassed or enveloped by another, it is thus more easily exposed to the solvent; and from the great utility of this practice when chemical solvents are used, as acids or alkalis, arises the necessity of having mortars which are competent, as before mentioned (309), to resist the action of these and similar substances.

377. The use of heat in assisting solution is very great, and though heat and division may in many cases be resorted to almost indifferently for effecting the required end, yet the student should understand that they attain the object in different ways, that he may know in peculiar cases when to apply the one and when the other. Division is favourable merely by increasing the surface of contact between the solvent and the body to be dissolved; thus offering an immense number of points where the action may simultaneously be exerted, and in this way bringing it sooner to a close: whereas heat acts directly by increasing the power of the solvent, and enabling it to take up a larger quantity, and incidentally by causing a multitude of currents in the liquid, by which fresh portions are continually brought into contact with the body to be dissolved. Hence heat does not merely expedite the action, and in that way do what comminution effects; but it does actually increase it, and cause a greater portion of the solid body to be dissolved than would otherwise be the case.

378. A frequent use of the application of heat is that required to obtain a solution saturated when cold. It would take a long time, for instance, to prepare a saturated aqueous solution of white arsenic, by contact of the powder with

water, or even by agitation; but by boiling the water with the powder for half an hour, leaving it to cool, and afterwards filtering it, a saturated solution will be immediately obtained. The same is the case, though not so strikingly, with more soluble substances, as sulphate of potash, nitre, &c., and in these instances the object is generally effected by warming the pulverized substance with the water in an evaporating basin or flask, over a lamp or sand-bath, or by using warm water with trituration in the mortar. With the exception of the two or three salts which are scarcely more soluble in hot water than in cold, the attainment of the object should be ascertained by observing whether the hot solution has deposited any portion of the solid substance during its cooling: if it has, it proves the saturation, if it has not, there is reason to doubt it, and heat, with more of the solid substance in powder, should again be applied.

379. An easy method of testing this point of saturation, even whilst the solution is hot, is to dip a glass rod into the liquor, and by means of it to transfer a drop to a cold glass plate (1348): if a deposition of crystals or solid substance appear in a few moments, then the solution will be saturated when cold. If they do not appear immediately, still the student should not be satisfied, until he has stirred the drop with the platina spatula, and repeatedly struck the glass beneath the solution with the metal; this will frequently cause a precipitation of crystals to take place, which would not otherwise have appeared except in a long time, and they equally indicate that the solution when cold will be saturated. Ultimately the solution should be filtered, if necessary, to separate any mechanical impurity.

380. When the object of applying heat to increase the solvent power is not simply to obtain a saturated solution, but to accelerate a process which, either from the previous combination of the substance with other bodies, or the want of action at ordinary temperatures, would be tedious and imperfect, if not urged by all the means at command; the application has to be continued for a longer time, and frequently in vessels which will retain the vapour more perfectly than a basin. The ebullitions and digestions which

are sometimes continued for a long period, are processes of this kind, and the choice of the vessel will depend upon the circumstances attending the action. Basins and open vessels are convenient, because they afford a ready access to the liquid, either for the purpose of removing portions for examination when necessary, or for stirring and agitation. For this reason, when the dispersion of a little vapour, or even of a little of the substance by ebullition, is of no consequence, basins are very convenient, and they are necessarily used when the substances are operated upon in such a form as prevents their introduction into flasks. But when it is desirable to retain the vapour as much as possible, as whilst using acids, or when it is necessary that all loss from ebullition be avoided, or all possible contact of extraneous substances prevented, then flasks are most useful, and especially Florence flasks. Hence almost all solutions relative to analyses, if they require the aid of heat and occupy time, are most safely made in flasks. The selection of a basin or a flask in any particular case must be left to the judgment and experience of the operator.

381. In these and similar cases, all sudden applications of heat, especially to glass vessels, should be avoided. A glass flask, unless it be very thin, when filled with a cold fluid, and set suddenly in a hot sand-bath, is almost sure to break. If it be required to heat a basin in a sand-bath, the bottom should previously be dried, for if wet, the water, by contact with hot sand, becomes rapidly converted into vapour, which, causing a slight explosion, sometimes throws the sand into the vessel. The elevation of temperature is accelerated by covering the basin and preventing evaporation. This is often conveniently done by putting a second basin somewhat larger over it, its cleanliness having been previously ensured. If the fire or sand-bath be such that it is advisable to obtain the heat as rapidly as possible, no fear of injury being entertained, then on putting down the basin it should not be set upon the top of the sand, or pressed down a little way only, but the sand should be removed with the iron spatula before mentioned (174) to the sides, the basin set down upon the bottom of the bath, or

with only a very thin layer of sand intervening, and then the sand returned round the sides of the basin. The thickness of sand which may be allowed to remain between the bath and the bottom of the basin, must be left to the judgment of the experimenter, being proportionate to the heat of the fire under the bath, the previous heat of the sand, and the quantity and nature of the substance to be heated. It is in general advisable not to heap the sand round the sides of the basin to a greater height than the solution inside, at least if the sand be hot, or likely to become so during the operation; for it then sometimes makes the part of the dish above the solution very hot, and when ebullition happens and raises fluid over it, the sudden change occasions fracture, or gives rise to the production of much steam, which endangers the boiling over of the contents of the vessel.

382. If it become necessary to add water or a cold liquid to the contents of a hot basin upon the sandbath, the additions should be made with great care, for if the cold liquor be poured at once into the hot, it will pass through it, and striking against the bottom of the hot basin, will very probably break it. Hence, to avoid too sudden a change of temperature, the cold liquid should be added slowly, and poured into different parts of the hot fluid.

383. When a flask is put upon the bath, it should be sunk more or less deep according to the heat of the sand and the heat required, and hotter or cooler parts of the bath may be selected for the same reasons. Hence one advantage of the table-furnace before described (169), whose sand-baths present every required degree of temperature. If a situation be too hot for a flask, making its contents, for instance, boil very rapidly, the heat is easily diminished by raising up the flask more or less, and allowing the sand to sink under it; this not only causes a thicker stratum of sand to intervene between the bottom of the bath and the flask, but also removes a part of the flask out of the sand altogether.

384. When a flask on the bath is to have its contents heated as rapidly as possible, it is frequently safer, instead of endeavouring to apply a stronger heat at the bottom, to

prevent dissipation of heat above. This is very usefully effected by a tin cone about seven inches in diameter at its base, six inches high, and having a hole where the apex would otherwise be, about an inch in diameter, through which the neck of the flask may pass. This case, slipped



over the flask, and resting at its lower edge on the sand, forms a hot chamber round the upper part; the air within it actually assists at times to heat the flask and its contents, and in all cases materially interferes to prevent cooling. Even the space left open round the neck may be closed when desirable, by passing a piece of card, with a hole cut in it, over the neck, that it may rest on the upper edge of the cone.

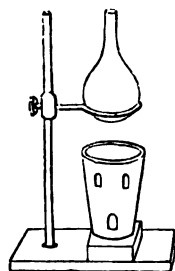
385. When a flask in a state of ebullition on the bath seems on a sudden in danger of boiling over, it should instantly be lifted up if possible, but at the same time the operator should blow with his mouth against that part of its surface which is above the level of the fluid. This will generally cause condensation of the steam within, the ebullition will diminish, and the contents be secured. An expedient of this kind will often save the contents of a flask when the neck, from being full of froth, is too hot to be touched by the hand; upon its descent the neck will become cool, and may be laid hold of. When flasks are upon the sand-bath, a list ring or two (68) should be on one side, ready for the reception of the flasks in case of emergency.

386. When a small charcoal fire or a lamp is the source of heat, the basin or flask has to be supported above it. This may be done either by a ring tripod, as delineated in the wood-cut, or by what are called retort stands. With the tripod the height is fixed, and hence the lamp or furnace may require elevating. For this and numerous other purposes of adjustment in the laboratory, the wooden blocks before described (20) are continually of use.



Retort-stands are sold by the instrument-makers, and consist of an upright brass rod fixed on a heavy turned foot, and furnished with rings, which being each

fixed to an arm, and that to a socket, the latter passes freely up and down upon the brass rod, and is made tight at any particular height by a screw-nut at the back (448, 465). In this way the facility is obtained of fixing the projecting rings at any height required, and as several of different sizes accompany each retort-stand, vessels with globular bottoms, or indeed of many other forms, may be supported at any required height. It is easy, by these stands, to support the flasks or basins at the proper distance above the lamp or furnace. When, from the weight of the vessel and its contents, it is too heavy for the arm, or would cause the stand itself to tip over, then two stands may be used on opposite sides, the ring of one being placed under the other, and the flask or basin on the uppermost. These stands are generally made with small circular brass feet, filled with lead, but which still are insufficient to retain the whole upright when a heavy vessel is on the ring. It is much better to



make the foot of a piece of stout board, about twelve inches in length, six inches in width, and an inch thick. The upright rod should be fixed about one inch and a half from one end of it, the lamp or furnace should be placed upon it, and the ring of course in a corresponding direction. Such an arrangement is perfectly steady, and cannot be overset by any weight which it is strong enough to bear. When the usual stands only are at hand, it may now and then be necessary to put on a second ring in an opposite direction to the first, and to add weights for the purpose of equipoising the whole.

387. When a flask will not fit very well, it may be hung up above the lamp flame by a cord, for which the common shape of the neck is well adapted: this arrangement may often, on other accounts, be desirable. A few triangles of different sizes, made of stiff wire, will often facilitate the adjustment; these resting on the rings of the stand, sustain the retort at three points, and keep it very steady.



388. When a crucible furnace is used it should always be

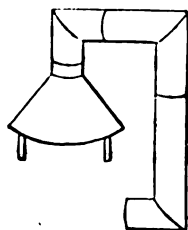
placed on a tile, and not immediately upon the wooden table or stand, lest, during a long operation, it should become heated to the bottom and burn the wood beneath (1357). The tile also catches hot falling ashes or sparks, which would burn the wood, and it facilitates the removal of the furnace in the hottest state without inconvenience. A lamp requires no precautions of this kind. When operating with flasks and retort-stands, care should be taken that a flask, which, with its contents, has been heated, be not suddenly put upon a cold ring, and that a cold flask just charged be not placed over the fire upon a hot ring; in both cases the bottoms of the flasks will probably come out, and the contents be lost.

389. When it is desired to keep a flask with its contents in a state of ebullition over a lamp, it may generally be effected by adjusting the flame. But a facility is gained by having the heat somewhat greater than is sufficient when the lamp is under the centre of the flask, and adjusting the effect by moving the lamp a little on one side. The application of the heat is smaller or greater in proportion as the lamp is removed from the centre; but at the same time, being applied on one side, a cooling process goes on more decidedly at the other than before; and this, with the uniformity of the current established within, makes the whole operation more regular.

390. If the effect obtained by a lamp is hardly sufficient, and yet from circumstances is the most desirable source of heat, the tin cone (384) is then a very essential adjunct. When slipped over, and allowed to rest upon the flask, it confines an atmosphere of very hot air about the upper part, by which the time of heating is shortened, and in many cases it assists in the attainment of a temperature which could not otherwise be acquired. The cone should be guarded at the upper part within either by a layer of thick paper, thin pasteboard, or some such substance, or by a ring of cork, to prevent the metal from touching the glass; a circumstance which might now and then, from difference of temperature, produce fractures. The exterior should be preserved clean and bright.

391. In many cases of solution, the vapours emitted, either from their acid nature or noxious qualities, are highly injurious; wherefore it is desirable, as much as possible, to convey them away, and to prevent their mixture with the atmosphere of the place. Hence the use of the large hood before referred to (10), which, receiving such vapours, conducts them into the flue. A hood to be useful should descend low, and as closely as possible over the place from whence fumes are to be carried off; but this necessity often makes a large hood inconvenient. To be effectual, it should also have a good draught passing through it.

392. A temporary moveable hood is a useful appendage to the table-furnace before described (169). It consists of a cone having its lower diameter equal to that of the round sand-bath (171), supported on three short legs to rest within the edge of the bath, and opening above into a funnel-pipe, which, by three bends at right angles, is made to terminate opposite the fire door. The pipe



is conveniently formed, in two or three pieces, the whole being of copper; the cone itself, and the pipe and joint above, may be made of copper, or very advantageously of stone-ware. When placed upon the sand-bath, with the door of the fire partly open, and the end of the pipe opposite the aperture, such a draught is occasioned through the whole as will carry off any fumes which may be liberated beneath it into the chimney.

393. The inside of a hood of this kind should be kept clean, to prevent the possibility of dirt falling from it into the vessels beneath. When the vessel is a flask, an additional security is obtained by covering the mouth loosely, either by inverting over it a short tube, closed at one end, and sufficiently large, or by placing upon it a convex fragment of old glass from a retort or flask. When the vessel is a basin, it may, in some cases, be similarly guarded by another basin, placed over it as before mentioned (274); when that cannot be done, the cleanliness of the hood should be particularly attended to.

394. When the contents of a flask evolve vapour spontaneously, or require but little heat to produce them, the flask may be placed upon a listed ring (68), in an inclined position, and have its mouth directed to the ash-pit of the furnace: the draught will carry away the fumes whilst it is in that position, and, at intervals, it may be placed for a few minutes together on the sand-bath. Where the spare flues exist, which have been before referred to (5, 168), they are very useful in carrying off vapour. The mouth of a flask brought near to one will deliver all its vapours into the flue, and from the height of the latter, it is easy to arrange the flask, with its lamp or furnace, in a proper position. When the portable hood just referred to (392, 168), is adapted to the aperture of the flue, which may easily be effected when the pipe, as mentioned, is in two or three shifting pieces, nothing more can be desired; for, so arranged, a good flue is competent to carry off all the fumes from any basin which the hood can cover. Where the table-furnace is favourably situated, as against the side of the laboratory, no difficulty occurs in using a piece of pipe, which may be put up in a moment, and connect a moveable hood over any part of the sand-bath, with the flues behind.

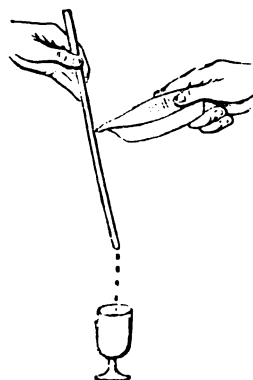
395. Besides these general directions for the process of solution, there are numerous precautions requisite to ensure accuracy, when results of the utmost precision are required, as in cases of analysis; amongst which are the following. If the quantity of solid matter operated upon has been weighed, it is of consequence that not a particle be lost in introducing it into the flask, supposing such a vessel to be used. The experimenter should not venture to pour it into the neck directly from the glazed paper in which it may have been weighed (61), or from any vessel that may contain it, but should use a small clean funnel for the purpose. If dry, the powder will probably pass freely through it, without adhering to the glass; but before removing the funnel, it should be washed with a little water, which will carry down any adhering particles. If, in passing through the funnel, some of the powder has struck against and adhered to the inside of the neck of the flask, that should

also be washed down to the bottom with a little water. The water which is used for these purposes should be distilled, and indeed, in all cases where accuracy is required, equal care should be taken on that point. It is much to be regretted that any laboratory should be so far restricted in the use of distilled water as not to have sufficient for every case of solution, whether for refined analyses or the most ordinary experimental processes (26).

396. When effervescence happens in the flask, precautions should be taken that none of the solution be lost. During a cold effervescence, as of carbonate of lime in an acid, the breaking of the bubbles will throw up a shower of particles, many of which will ascend several inches perpendicularly. In these cases, it will be right to incline the flask at an angle of about 45° , for then the rising drops will meet with and break against the side of the flask, and be retained. At other times, when strong currents of vapour or gas are produced at the same time with this dispersion from the breaking of bubbles, many of the particles may be carried away by the current, even when the flask or vessel may be considerably inclined. In these cases, the addition of the acid, or the application of heat, should be made cautiously, that the current may not become so rapid, and attain such power as to do harm. For the same reason, operations which are liable to occasion much effervescence, should be performed in flasks of the largest size, that the current of gas within may have less velocity, and that the particles may have room and time to fall.

397. On pouring solutions from glasses, flasks, or basins in the ordinary way, it is scarcely possible to operate, so that, on ceasing to pour, and returning the vessel to its first position, a small portion of the liquid shall not flow down the outside; or if successfully down once, there is no certainty that it can be performed whenever required. A failure of this kind occasions a loss of substance, which, when repeated, is quite incompatible with the accuracy of analytical processes; but it may be avoided by very simple means. A clean glass rod (374) is to be dipped into the solution to be poured, so as to have its surface at the end

wetted, and then, the vessel being inclined, the rod is to be applied in a vertical or highly inclined position, so that its wet surface shall touch the lip or edge from which it is



intended to pour. When, by further motion of the vessel, the fluid at last runs over its edge, it will proceed down the rod, being conducted by it in any required direction. When a sufficient quantity has in this way been removed, the vessel is to be restored to its first position, the rod not being withdrawn until the fluid is decidedly below the inside edge; all that is without will be confined to the surface of the rod, not a particle having flowed down the outside of

the basin. The rod may be left in the solution until a fresh portion is to be poured; or if no more be required, may be washed by a little water from the dropping bottle (402), which, being added to the original solution, prevents the loss of a single particle of the contained substance.

398. This application of the rod is not merely useful in preventing loss or waste, but also in conducting the fluid in particular directions, when other means are wanting. A solution, or liquid of any kind, which wets the rod, may be poured very accurately and securely into a narrow-mouthed bottle by it, if a funnel be not at hand, and occasionally it even surpasses the funnel in convenience. Thus in pouring successive small quantities of a valuable fluid, a rod enables it to be done safely, and at the same time with considerable minuteness, by allowing a very small stream to flow from its end, the vessel being in contact with the rod, but a little way above it; between each operation of pouring, the rod is conveniently and securely placed in the fluid. With a funnel, a much larger surface is moistened, which drains for some time after, and the quantity is by no means so well estimated as by the former method: neither in the intervals of pouring can the funnel be so conveniently disposed of as the rod.

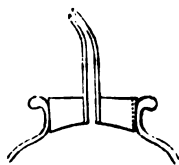
399. If upon any sudden emergency the pouring has to be performed without the guiding rod, and yet loss of the substance would be of consequence, then put the lip from which the fluid is to flow against the further side of the mouth of the vessel which is to receive, inclining the latter, if necessary, at the time.

400. The operations which have been described have frequently to be performed on a very minute scale (915). Hence the use of small earthenware dishes, platina capsules, and especially fragments of broken flasks (371), which, from their concave form, are exceedingly convenient for experiments upon drops of fluids. In operations of this kind, heat is applied, either by a small spirit lamp flame, obtained by pulling down the cotton before the lamp is lighted, or by touching the glass with the hot sand of the bath, or even by letting it stand upon the hotter part of the furnace plate. Instead of flasks, tubes are used in similar operations for making solutions in small quantities, the general management of which will be described in Sect. xvi. (917).

401. Instead of pouring out the fluid, it has now to be transferred in portions, each less than a drop, and this is best done by dipping a glass rod into the solution, and then, whilst more or less adheres to it, according to the quantity wanted, to touch a clean glass plate or a piece of a flask with it, and allowing the adhering portion to run down. If but little be required, only a small length of the rod should be dipped in, and if still less be required, even that small portion should be allowed to drain for a moment or two, before the rod is brought into contact with the substance to be moistened. On the contrary, if a large quantity be wanted, two or three inches of the rod should be dipped in, and the adhering fluid quickly transferred to the desired place; or if the most be wanted that the rod can lift, it should, upon being dipped, be taken out horizontally, and carried adroitly in that position to the place required, taking care, by slight but proper motions of the rod, to prevent such accumulation of the fluid in one spot as to cause a drop. By these means, a glass rod may be made to carry very different

quantities of fluid, affording great facilities in the practice of minute chemistry.

402. There is an instrument which cannot be dispensed with in the laboratory, and which, in the order of our arrangement, first comes into service in the present chapter—it is the dropping-bottle. Its use is to supply small quantities of water, and the laboratory should be furnished with two of them, one to deliver large and rapid drops, or a small stream, the other to supply very minute portions for such experiments as those just referred to. The larger one may be a bottle holding about half a pint, and should have a good smoothly cut cork fitted into its mouth. A piece of strong glass tube, of an internal diameter not more than the eighth of an inch, should be selected and drawn out, so



as to have a contracted aperture, which, at the same time, should be bent on one side; the piece of tube should be about two and a half inches long, and fitted tightly into the cork, its extremity not passing inwards beyond the cork; and it is an advantage that the surface of the latter should be slightly concave or conical, as in the accompanying section. Lastly, a notch is to be cut in the side of the cork, diminishing considerably from above downwards, so that when the latter is in its place, the notch may form a passage into the bottle, with a narrow opening at the inner surface. This slit is to be on that side of the cork from which the upper extremity of the tube inclines.

403. The bottle is to have distilled water put into it, and being then placed in different positions, it will supply a stream of water variable in its quantity at pleasure. If inverted, it will be found that a small stream will flow out at the beak, and a current of air enter at the notch to supply its place. If the bottle be inclined, keeping the notch uppermost, the stream will not be so rapid, and in consequence of the diminished perpendicular height of the column of water tending to descend, occasioned by bringing it nearer to a horizontal position, the stream will at last break into single successive drops, which by a still further

motion of the hand also cease to fall. If a small portion of water be required to make a solution, it is readily supplied even to single drops; and smaller quantities are easily lifted and transferred as before described, by a glass rod (401). Or if a stream be wanted to wash the solution from a rod or a funnel, or to wash out a glass, it is instantly obtained. By allowing the stream or drops to fall from a greater or smaller height, variations in the descending, and consequently washing force, are produced; this may even be increased occasionally, by a downward jerking motion of the hand, which will throw out forcible independent jets of water.

404. It is proper to have a smaller dropping-bottle ready for use, because, from the infinite variety in the quantities to be operated upon by the chemist, such an instrument will at times be found advantageous. By making the tube smaller, a similar set of capabilities to those just described, but with a smaller stream of water, are obtained, and a minute quantity of a rare substance of which it is desired to save every atom may be operated with, yet without more dilution than is absolutely necessary.

405. The selection of solvents for particular substances is an important point, which must, however, in a great measure be left to the judgment and knowledge of the student. If the object be to ascertain the properties of a substance by working with its solutions, water should be first tried. If it have no action, alcohol may be used, and after that ether, pyroxylic spirit, and finally, on some occasions, oils. As a general rule, those solvents are to be preferred which are evaporable, and may therefore be dissipated by heat, and which at the same time least effect the chemical powers of the substance to be dissolved. In these properties, and in economy, water surpasses every other body that can be used.

406. Mixtures of water and alcohol are frequently useful, where neither water nor alcohol alone is applicable. Thus if muriate of soda and sulphate of lime were mixed together, the muriate is best dissolved by water; this, however, would occasion the solution of a portion of the sulphate of lime,

whereas by a mixture of one part of alcohol and two or three parts of water, a solvent is produced which will separate the former salt and reject the latter.

407. When an aqueous solution of a vegetable substance has been made, which on examination is found to contain different substances, some soluble in alcohol and others not (and there are few infusions of vegetables that do not yield such a mixture), it often has to be subjected to the action of alcohol for the purpose of effecting a separation. The first step is concentration by evaporation; but it is advisable not to carry this to dryness, or as far as may be without injury to the substance, and then to act by alcohol; for generally a soft mass is obtained, upon which alcohol acts only imperfectly except in a long period, because the last portions of soluble matter are protected by the mass of insoluble substance. It is better to suspend the evaporation when the substance is a thick fluid, and then to add a small quantity of alcohol; which, although it will cause a partial solution and partial precipitation at first, will, upon being stirred, mix with the fluid, and be overpowered as it were by the water still remaining, so that the precipitated portion will be redissolved, and the *whole* again rendered fluid. This should be repeated twice or thrice, stirring each time, and keeping the mixture of uniform consistency; a precipitation will gradually take place, increasing as the proportion of alcohol is increased. The particles thus rejected as insoluble will be nearly free from any mixture of substance soluble in the alcohol, if at least there be no chemical affinity interfering, and thus a ready solution of the one part, and its separation from the other, may be effected. The quantity of alcohol added must be such as at last to surpass by many times the quantity of water left at the close of the evaporation, otherwise its powers will be diluted, and a complete separation of that which is soluble from that which is insoluble will not be obtained. Hence the evaporation should be carried as far as possible, so that the residue be fluid and will mix readily. If it be so thick that it clots upon adding the first portion of spirit, a few drops of water must be added. The solution should be in such a state that the first portion of

alcohol, equal to about a fourth of the bulk, should cause precipitation, which disappears upon stirring; the second portion cause a turbid liquor after stirring; the third, an increase of turbidness but still no clotting; the fourth, when an equal volume has been used, a separation of the precipitable part in softer or harder masses. When three or four times the volume has been added, it will generally be found that the separation is complete.

408. Some of the acids frequently act as mere solvents: their power apparently not being due to powerful combination effected between them and the substance by which a change of character is produced. Thus acetic acid dissolves caoutchouc, and acetic, nitric, muriatic, and some other acids, dissolve phosphates and borates. Muriatic acid dissolves sulphate of lead, and to a slight degree muriate of silver, and many other such actions will be observed in the course of experimental investigations, all of which should be remembered, and may in turn be put to important uses.

409. When acids and other energetic chemical substances soluble in water are used, either as simple solvents or as producing compounds by combination, attention should be paid in their selection to certain general advantages which each possesses. Nitric acid is distinguished as a chemical solvent by the solubility of almost all the salts which it forms; by its imparting oxygen to metals generally, so as to bring them into a soluble state; and by its ready separation from all its compounds at a sufficiently high temperature, — three circumstances of very great importance. When used, care should be taken that it is sufficiently diluted: very strong nitric acid will sometimes seem to have no power over a body at common temperatures, when, upon the addition of a little water, action will immediately commence. This circumstance never occurs with acid which has been diluted with one half its bulk of water. Any further dilution, therefore, can only be required to moderate chemical action, and not to commence it. Muriatic acid yields salts generally soluble, though some of them are but slightly so; and muriate of silver not at all so in water. Many of the resulting compounds are fixed at a red heat,

tions of sugar, and also, though to a less degree, in solutions of extract and other vegetable matters: hence they are retained in solution at times in very unexpected situations, and might give rise to much uncertainty in the appearances and characters of other substances, unless the experimenter were aware of the general fact. Platina is not itself soluble in nitric acid, even when spongy, and in its most comminuted form, but when alloyed in small quantities with metals dissolved by that acid, it becomes soluble with them, and, in consequence, appears now and then in situations where it is not expected.

413. Tartaric acid or tartrates have an extraordinary power of rendering many metallic oxides soluble, which are not so by other acids without it; and still more in holding them in solution when such substances are added as in ordinary circumstances effect their separation. The oxides of bismuth, antimony, tin, and titanium, are easily dissolved by acids when tartaric acid is present; and being present, ammonia no longer has the power, upon its addition, of separating the oxides of iron, titanium, manganese, cerium, cobalt, nickel, lead, antimony, and the earths, alumina, magnesia, and yttria, from their solutions, and, in certain cases, even potash or soda fail so to do. Great advantage may be taken of this property occasionally, but sometimes it is equally disadvantageous in preventing the usual action of re-agents.

414. A very numerous class of aqueous solutions is produced by metallic salts. These, in consequence of the varied quantity of oxygen with which many of the metals can combine, are susceptible of changes dependent upon the oxygenation of the metal whilst the state of solution is continued. These changes are eminently useful in fitting the solutions in one way or another for experimental purposes. If the object be to oxidize the metal, whether to render it soluble, or for any other purpose, the agents to be employed are the acids generally, nitric and nitromuriatic acids especially, chlorine and chlorate of potash, and in some peculiar cases, even alkalis. Metals generally will dissolve in water or an acid only when combined with oxygen, and, in

obedience to this law, sulphuric and phosphoric acids, and perhaps muriatic acid, frequently cause the decomposition of water for the oxygenation of the metal. Nitric acid is often decomposed, supplying a portion of its own oxygen to the metal with which it is in contact. Proto-salts in solution are frequently converted into per-salts by it, and also by nitro-muriatic acid and chlorine. A proto-sulphate, muriate, or nitrate of iron, may be converted into a per-salt by a little nitric or nitro-muriatic acid and heat; and a proto-nitrate by heat alone. The same agents are equally effectual in converting proto-salts of tin into per-salts. In these cases of conversion, care should be taken that no acid be added that will interfere with the future experiments, or that may not be dissipated by heat.

415. The influence of alkali in causing oxygenation may be observed by putting a little oxide of chrome or a salt of chromium into a solution of alkali, so that the latter may be in excess; by evaporation to dryness in a platina capsule, and heating the mixture with access of air, the oxide of chrome will absorb oxygen, and become chromic acid, through the influence of the alkali, with which it will ultimately combine.

416. If deoxidizing agents be required for the metal in solution, then an efficient one is most likely to be found amongst such bodies as alcohol, ether, sugar, gum, &c. Of the known metals, per-salts of manganese are reduced to the state of proto-salts by being boiled with alcohol or ether, and become quite colourless: solutions of platina and palladium are actually reduced by boiling with alcohol. The per-oxides of lead and manganese, when mixed with any of the bodies enumerated and an acid, are reduced to the state of protoxides, and dissolved, if the acid be such as to form soluble salts. If a chromate have excess of acid added to it, with a little of any of the same substances, and be heated, it loses oxygen and becomes oxide of chrome, which, with the excess of acid, forms a salt. These facts are mentioned generally rather than particularly, that being combined with the pupil's previous knowledge, they may assist him in surmounting a difficulty, and in devising the most expedient

~~process~~ by which he may attain his objects. The processes of analysis and research require to be so infinitely varied under different circumstances, that every possible action and every practicable expedient is necessarily resorted to in turn to enable the experimenter to proceed.

417. The general principles and directions given with respect to the solution of inorganic matter will apply to a great extent to that of organic substances. The few differences that occur depend upon the situation of the matter to be dissolved, and upon its destructible nature. The active principles to be separated are generally in small quantity compared to that of the inert enveloping substance, and the latter is often easily affected by powerful agents, such as acids and alkalies, and converted into bodies which, though useless, are soluble, and would contaminate the solution. Hence it is necessary to select such agents as, at the same time that they act with energy on the principles to be dissolved, have no power over the accompanying matter. Acids and alkalies are therefore objectionable. Indeed a still more cogent reason exists for their rejection in general, namely, a reaction upon, and destruction of, the peculiar principles themselves. Hence a frequent recurrence to such solvents as water, alcohol, and ether, either cold, or aided by heat; and if acids or alkalies are used, they should be diluted and applied only after the other solvents have exhausted their powers, or for the separation of known principles to which their action is favourable.

418. M. Robinet has recommended the use of neutral saline solutions in particular cases *, stating that a separation of principles may be sometimes effected by them, where water dissolves the whole or else acts only imperfectly.

419. The original vegetable or animal substance, if dry, may be rasped or bruised (333, 357), so as to be divided into small pieces, but not generally into powder. If the action required be but short, hot water poured over the substance in a basin may be sufficient: but if a longer time be required, the mixture must be retained in a sand-bath, or

* Annales de Chimie, xxx. 208.

over a lamp, as before. When hot water is merely poured upon the substance, the process is named *Infusion*. When the heat is continued for some time by the application of fire, *Decoction*; and when it consists of pouring cold or warm water on the substance, and allowing it to stand for some time, it is called *Maceration*.

420. A very excellent and useful process of solution is called *Lixiviation*. It is applicable only to such substances as from their porous nature are permeable to water, and consists in the separation of a soluble body from an insoluble one by washing. For this purpose the mixture is to be loosely arranged, and water added till it fills all the cavities, and covers the surface of the mass. In the laboratory it may be conveniently performed in the small way in a funnel, and shall, therefore, be so described. Suppose it were necessary to wash the salts from a quantity of ashes: a funnel of sufficient size should have the lower aperture stopped by a cork, and should be supported on a stand, so that it may steadily retain its proper position. A few pieces of the ash, of such size that they shall not pass through the neck of the funnel, should be introduced in the first place, to prevent the descent of the matter to be placed over it. Having added pieces rather smaller, until the surface exposed in the funnel is an inch in diameter, the rest should be crushed in a mortar to a coarse powder, or rather to small pieces or grains, and put into the funnel above that previously arranged. If the substance be such that it will not afford lumps of sufficient size or strength to remain in the neck of the funnel and support the rest, then its place should be supplied by some pieces of broken glass, which may be continued to the height before mentioned, and which, while they support the substance, afford abundant passages for the fluid when required. Being thus far arranged, hot or cold water is to be poured into the funnel according to circumstances, its quantity being such that it will just cover the mass. The whole is to be left in that state for a time proportionate to the solubility of the substances present. The water which has penetrated the fragments will gradually dissolve the salts, and forming a heavy

solution, will descend in the free spaces, changing situations with the water not yet saturated. In this way a solution will be produced of much greater strength below than above, and the upper part of the mass will be washed almost perfectly at the first operation. When sufficient time has been allowed, according to the quantity and nature of the salt, and the manner in which it is enveloped, the cork beneath should be withdrawn, and one-half or two-thirds of the solution suffered to run out gradually, not hastily, lest greater disturbance of the solid matter in the funnel be occasioned than is necessary or advantageous. The cork is to be replaced, fresh water added above, so as not to disturb the arrangement; and being left as before for a time, the second solution should then be withdrawn, and this operation repeated till the water which passes is perfectly free from salts, or contains so little as to make further attention unnecessary.

421. This process of displacement is very often useful when the soluble parts of vegetable substances are to be taken out. Thus, if coarsely powdered galls are put into a funnel closed below, or into any other vessel fitted to perform its office more conveniently, and then enough water or spirit, as the case may be, added as will just cover them, and the whole left for several hours or a day, at the end of that time the solution will be very strong. Then if more water or alcohol be added above carefully, and the aperture below be opened so that the fluid shall pass slowly out, it will be displaced and replaced by the fresh fluid above, and all that is soluble be thus very well extracted. As before remarked, this operation can only be performed on such substances as permit access of water to all parts. When the particles fall together, or adhere slightly, and so prevent contact of the water, and choke up the channels, then recourse is sometimes had to the intermixture of inert matter, as hay, straw, coarse sand, or broken glass; but it is better in such cases, when they occur in the laboratory, to put the substance into a basin or glass with excess of water, and by agitation every now and then, effect the solution in the usual way.

SECTION VII.

DISTILLATION.—SUBLIMATION.

422. DISTILLATION and sublimation have the same object, and require nearly the same means; both consist in the conversion of a body into vapour, its transference in that state, and consequent separation from other substances, and its ultimate condensation. The difference generally consists in the state assumed by the vapours when condensed; if the product be solid, the process is called sublimation; if liquid, distillation. All that is required is, that the substance to be distilled or sublimed should be raised to such a temperature, that it will assume the gaseous form, and in this form conducted into a receptacle of such temperature, as to cause its resumption of the fluid or solid state.

423. Simple as is the process in theory, there are few that are liable to greater variety of arrangement. The range of temperatures at which different bodies rise in vapour is very extensive; for sulphurous acid or chlorine assumes that state at temperatures below the freezing point of water, whilst mercury or zinc require one verging upon, or even surpassing, a red heat. Thus, on the one hand, very low temperatures are required to effect condensation, and, on the other, very high ones to cause the requisite vaporization. The vessels and the apparatus to be employed must not only be adapted to these points, but also effectually to meet the innumerable varieties in the quality and quantity of the substances operated upon (924).

424. The common still will serve best to exemplify the ordinary points requiring attention in the process of distillation. It may be used both for water and alcohol, and if the laboratory be not otherwise supplied with distilled water, must continually be had recourse to for that necessary article (26). The still consists of a metal boiler to contain the water to be purified; to this is adapted a head, which terminates in a beak, and the latter is made to fit into the commencement of a spiral tube called the worm, fixed in a tub,

the whole of this part being called the refrigerator. The process consists in raising the water into vapour in the still, and condensing that vapour in the worm; the condensed water runs out, and is received at the lower extremity, which ought, in all cases, to be left open.

425. It will be necessary to preserve a sufficient fire under the boiler during the distillation, not merely to produce ebullition, but also to cause the water to boil rapidly, so as to afford a quick succession of vapour, otherwise the operation will be very tedious. It is important, in all cases, to keep the top of the still hot, or the vapours will condense there, and, flowing down the sides to the water below, will be again vaporized, and cause great waste of heat. For this reason it is useful, when the top is exposed to the air, to cover it with a dry cloth, this precaution being continued to the descending part of the beak or pipe. It is also necessary to observe that this pipe be sufficiently capacious for the passage of the steam to the condenser without any obstruction: every thing in this part of the apparatus should be arranged so as to generate vapour with great rapidity, and to convey it with corresponding readiness to the worm. The student must not forget that as the water is distilled, its quantity will diminish in the vessel, and should be replenished before any injury arises from its deficiency.

426. The vapour having reached the worm is there to be condensed; and therefore the worm is put into a tub and surrounded with cold water, the low temperature of which causes the substance to lose its elastic form, and flow out in the liquid state. From the quantity of heat communicated to the refrigerating water, which is greater as the operation is more successfully carried on, it will become necessary to change it readily and quickly, and many contrivances have been resorted to for this purpose, amongst the best of which are those that supply a constant stream of cold water to the bottom of the tub, and draw off an equal quantity of hot from the top. Whatever the arrangements are, the water must never be allowed to become hot, or if it does so at the surface, it should be but moderately warm at two or three inches beneath; for, although in some cases it may happen,

that when the upper half of the water is hot, the lower half may still be sufficient to condense the steam, yet inconveniences often arise. Amongst these is occasionally one of more consequence than mere failure of condensation; this is, the obstruction occasioned to the passage of the steam, when it has to force its way uncondensed through several coils of small hot pipe, and which, at times, may become so great as even to cause the forcing up of the head of the still. As before mentioned, any obstruction to the free liberation and condensation of the steam interferes with the effectual working of the still, and causes a consequent loss of heat and expense of fuel.

427. The water which flows out at the end of the worm should never be more than warm. It may be received and preserved in stone bottles, and should always be tested, that its purity may be known. The end of the worm should not usually be allowed to dip into water, so as to close the aperture, as in that case, from irregularities in the liberation of steam, much agitation is now and then produced; and, at a moment of inattention, the water which has been distilled may actually return back into the boiler, from a partial condensation therein.

428. The vessels in which most laboratory distillations are effected, are retorts (16) and flasks (372). Retorts are of every size and shape, and of very various materials; those made of glass are equal to all operations which may be conducted at temperatures less than that at which the glass softens, and by luting may be used at much higher. They admit of constant observation of the materials within, are acted upon or injured by very few substances, and may be cleaned, generally, with facility. Their great point of failure is that of brittleness, which endangers both the apparatus and its contents.

429. With regard to the general form of glass retorts, it is not of any very great consequence, as respects their use in distillation and sublimation: they will be required with necks of very different lengths and dimensions, and with bodies of various proportion as relates to the necks; the general proportions may be nearly those of the accompany-

ing figure. But the case is different when they are intended for exhaustion, as in numerous pneumatic experiments (866); for having then the pressure of the atmosphere to support on their exterior surface, their form should be carefully attended to. Retorts that are care-



lessly bent in the making, are liable to two imperfections of form, which frequently weaken them so much as to render them unable to bear exhaustion; the one is a flattening of the convex surface at *a*, and the other is a sharp fold or double in the glass at the opposite part *b*, which expands the two sides (at *c*), so that a section made through those parts would have a resemblance to a long flat ellipsis. Such a shaped retort will rarely bear the pressure of the atmosphere on the flattened parts, but will crack during exhaustion at *c* and the opposite corresponding side, or will be shattered and crushed to pieces. Retorts should therefore be generally chosen sufficiently convex in all parts, the degree of curvature of one part passing gradually into that of the neighbouring portions, as is represented in the figure. Such a retort, though very thin, will bear exhaustion with perfect safety; and that a sufficient number may be on the shelves when required, let *all* be selected with a view to such an application.

430. With regard to thickness, retorts should be examined as directed for glass flasks (372); the bulb should be uniform, or nearly so, throughout: if there be any difference, the part at *d* should be thinnest, gradually thickening to the neck. All should be rejected of which the part at *d* is thicker than elsewhere, the application of heat being almost sure to break them. The general thickness should be that of flasks of about the same capacity, except that small retorts are better rather thicker in proportion to their size, or even occasionally as thick as the large ones, because they are more frequently subjected to temperatures at which glass becomes soft. All retorts with spots or grains of sand in the part to be heated should be rejected; they are liable to fly at those places.

431. The sizes of retorts, on the shelves, should vary, in the capacity of their bulbs, from two ounces to two pints. A few large ones may be at hand, on a bye-shelf, for particular uses.

432. Retorts are either tubulated or plain. When tubulated (465) they are more likely to crack, from the irregularity of form and thickness of glass at the juncture, than when plain; but, being very convenient in particular cases, by allowing easy access to the interior of the retort, some will be required. The aperture should be in such a position as to open into the body of the retort freely, admitting a funnel or a rod into it without interfering with the neck, and yet as little beyond the curve where the neck commences as possible. The tubulature is safest when it is not much thicker than the retort at the part where they join, but should thicken upwards, and be sufficiently strong to admit of having a glass stopper ground into it in a tight and secure manner. When the tubulatures are put on like a thick knot of glass, they soon break off, and the retort is of course destroyed.

433. In all cases where ground-glass stoppers are used, and they are very numerous, though this of the tubulated retort is the first we have arrived at, they should be examined, and the accuracy of the grinding ascertained. They should be so ground as not to be liable to fix and become immovable, and be so accurate as to remain airtight for months and even for years, when a little pomatum, or, rather, hard tallow is put round them. A stopper should be slightly conical, so that, when introduced, it may at once obtain its place, and bear on every part of the ground surface. Being moved round in its situation, it should feel perfectly steady and firm in the aperture, in every part of the revolution; and more accurately to prove the regularity in the hole and the stopper, by which they come in contact in all parts, the stopper should be pressed sideways in different directions, and in different parts of the revolution, to find out, if possible, any one position in which it shakes a little in its place;—none such ought to occur. This ascertained, a little tallow should be put upon the stopper, both

that and the aperture being clean and dry, and being then again introduced and turned round, a film of the fallow will intervene between the two surfaces of glass, which, at the same time that it occasions perfect freedom of motion in the stopper as regards its turning round in the hole, does not at all render it less firm and steady in its bearing than before; and it perfectly closes the passage, so that no portion of liquid or of gas can pass between them. If a stopper is not tight, it is easy to render it so by grinding (1230).

434. Finally, with reference to the state of the retort, it should be observed, that no retort, when once cracked in any part near the bulb, should be used in cases where heat has to be applied to liquid contents. Their use must then be confined to cold operations, or to sublimations in unimportant experiments.

435. A student has many points to attend to relative to the charging of retorts, or the method of introducing substances into them. If a substance in the state of lumps or of powder is to be put into a plain retort, and it is required that the neck be preserved in a clean state, the best preparatory step is to insure the cleanness and dryness of the retort (1251, 1252), so that no portion of the substance shall have any tendency to adhere to the glass. If it be a powder, it should fall down one side of the neck; being introduced, if there be occasion, by a small clean funnel (395). It should not be thrown down in a careless way, while the neck is held in a perpendicular position: by holding the retort in an inclined position, the powder is less separated, and adheres less to any part of the internal surface. If it be in lumps, they should be made to slide down one by one, the neck being inclined at an angle of 40° or 45° . If held more upright, or the pieces be heavy, there is a probability of their passing through the retort by their momentum. The retort must not be held with the bottom of the bulb downwards, for then the pieces as they pass from the neck will fall suddenly upon, and almost certainly break it; but it must be turned half way round, so that as the piece descends it may pass over that part which, when the retort is in its right position, forms its internal upper

surface. In this manner masses of metal and other heavy substances may be introduced without endangering the vessel. When the retort is tubulated, precautions relative to keeping the neck dry and clean are not so necessary, because there is no occasion for soiling it. The powder may be introduced by a funnel as before, and even washed in with a little water (395); and masses may be introduced also at the tubulature, not dropping them, but allowing them to slide in safely.

436. No instruction is necessary for the introduction of liquid, if a little waste, or the soiling of the vessel, be unimportant points; but when either of these are of consequence, the student should be acquainted with the methods of avoiding them. If the neck is to be preserved clean, as is often the case when acids are introduced, the end is easily obtained with the tubulated retort, by the use of a funnel with a beak so narrow and long, that it may pass into the body of the vessel. A few moments should be allowed for the funnel to drain, and it should at last be drawn out adroitly immediately after a drop has fallen, and before another is ready to descend; and during its removal the wet beak should be held so steadily as not to touch the side of the tubulature.

437. If the retort be not tubulated, then a funnel with a long narrow beak, sufficient to pass down the neck of the retort, and to reach the bulb at the end, must be used; or if such a funnel be not at hand, and the case is imperative, a piece of glass tube, rather longer than the neck, may be employed for the purpose, the fluid being carefully poured down the interior of the tube. In using the long-necked funnel or the tube, care should be taken that the end do not dip into the fluid already in the retort, for the exterior should be preserved clean and dry, that its removal may be effected without soiling the neck. For this purpose, when the funnel or tube has drained a few moments, it should be inclined with the retort, until the neck is nearly in a horizontal position, or even has passed it a little; that which was the lower end will now be the upper; and the fluid, still adhering to the inner surface, instead of flowing as before to the extremity, and gathering there in a drop, will

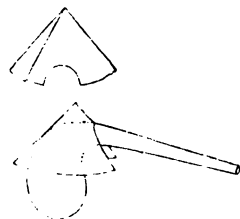
... corner course, leaving the end almost ... the tube or funnel may easily be with- ... without any risk of soiling it, if its ... prevented from touching the glass; for no ... can take place.

... size of a retort must be regulated by the quan- ... substance to be used, and by the kind of action ex- ... to occur. If the contents be fluid or semi-fluid, and ... liberation of gas or ebullition be expected, the charge ... should not occupy more than one-half or one-third the capa- ... of the bulb; or if the action be likely to be rapid, not ... so much; but if no expansion or swelling take place, nor ... any commotion by which particles may be thrown over; or ... if, in other cases, although portions are liable to be thrown ... into the neck, it be desirable to act on as much of the sub- ... stance introduced as possible, the charge may then occupy ... much more of the body of the retort.

439. The general methods of applying heat to glass retorts is the same with those adopted for heating flasks (381, &c.); and the spirit-lamp (199, 201), hot air (269), water, steam, and sand-baths (258, 271, 381, 176), oil-lamps (212, 386), and small crucible furnaces (386), may all be used in turn, with the precautions before given. Sometimes a little variation is required, dependent upon the following circumstances. In certain forms of distillation, the heat is applied merely to excite and increase chemical action; this is the case in the production of several gases from mixed materials; and in such cases, when the temperature has attained the necessary point, the application of heat must be diminished, until it is merely sufficient to preserve the temperature already acquired. In other cases, a greater resemblance exists to the process of distillation already described (424), and it is required not merely to allow a certain temperature, but to communicate heat for some time with more or less rapidity, that the liquid in the retort may be converted into vapour, and carried over. Hence the necessity of a command over the fire, so that it may be increased or diminished at pleasure.

440. The oil-lamp is of great service in chemical distilla-

tions, from its ready management, but sometimes scarcely yields heat enough for the performance of quick operations.



In such cases, the upper part of the retort should be covered, to prevent its being cooled by contact of the air, and this can often be effectually done by a thick paper or card-board cone, with a broad notch to admit the neck; this interferes with a ready change of the air at the top of the retort, and

saves much heat, which would otherwise escape at that part from the condensation of the vapour within.

441. The evolution of vapour is in many cases very much facilitated by the addition of substances having apparently no chemical action; and the process of distillation is not only thus facilitated, but rendered possible and easy, in cases where otherwise it would be almost unattainable. If diluted alcohol, spirits of wine, wine, or certain alcoholic solutions be distilled in glass vessels, the vapour is frequently evolved with difficulty; the contents of the retort at one moment not boiling at all, and at another bursting throughout into a mass of vapour and fluid, which fills the whole body of the vessel. This endangers the sudden expulsion of part of the substance, causing serious derangement of the process, and is also accompanied with such agitation of the fluid, such bumping and shaking of the retort, as at times actually to endanger the safety of the whole: for when the vapour is formed, it is with such force as to produce a dull explosion. This is prevented by the introduction of a few angular or fragmented pieces of solid matter into the retort, of such nature as not to be acted upon by any of the substances present. For this purpose metallic substances are the best; a piece of platina foil cut by scissors into narrow slips, so as to resemble a fringe, or seven or eight inches of silver, platina, or copper wire pressed up loosely, or platina and silver filings—are then very useful. So also is a fragment of cork or a piece of torn cartridge-paper, any of which will generally cause the regular and

tranquil evolution of vapour, and occasion the distillation to proceed quietly and satisfactorily.

442. The same effect takes place with sulphuric acid when distilled in glass vessels, but, from the weight of the fluid and the high temperature employed, with more force and more danger to the retort. In this case, the ill consequences which would result from the fracture of the vessel are much increased by the highly corrosive power of the substance at exalted temperatures. If, however, a piece of platina foil be introduced into the retort, the operation proceeds quietly, the vapour rises readily, and, with the exception of the high heat necessary, the distillation goes on as freely as that of water.

443. The student should be cautioned against the sudden introduction of these promoters of vaporization, whilst the fluids are hot. If, upon the occurrence of bumping during a distillation of alcohol, sulphuric acid, or any other fluid, in glass vessels, a piece of any one of the substances mentioned were suddenly introduced by the tubulature, it is probable that the consequent burst of vapour would be so instantaneous and strong as to do more harm than the bumping itself. The safer method is to remove the source of heat for a moment, then, opening the tubulature, to introduce a platina wire, letting it touch only the surface of the fluid at first, and introducing more of it as the ebullition occasioned by it ceases; when that is over, the wire should be withdrawn, the cork, the platina, or whatever, according to the nature of the fluid within, has been selected, be introduced, the stopper closed, heat applied, and the distillation proceeded with.

444. The effect of these promoters is best observed upon sulphuric acid. If two or three ounce-measures of strong sulphuric acid be put into a clean glass flask and heated over a small charcoal fire, as soon as the acid begins to boil, it will exhibit the irregularity described. The foil is then to be dropped in, and its power of forming vapour will be sufficiently visible. Sulphuric acid will boil several degrees lower in a glass vessel containing a piece of foil, than in one not so assisted.

445. The products evolved in distillatory operations may be considered generally as of two kinds ; vaporous, or such as may be condensed at ordinary pressure by the low temperatures we can command ; and gaseous, or such as resist these means, and hence have been called permanently elastic. Since the general relation of gases and vapours to each other has been distinctly explained and confirmed by experiment, this division is known to be very unscientific, but it is convenient in operations, and, being generally retained in chemical language, there can be no objection to it in this place. The operations of distillation here verge upon pneumatic manipulation : but as, in consequence of the peculiar means required for the retention and transference of gases, the processes relative to them will be more conveniently considered together, the further directions in this chapter will be confined entirely to such operations as relate to condensable substances.

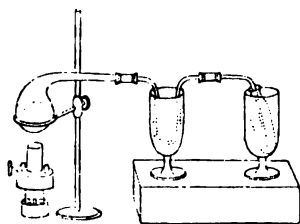
446. Retorts being used for the purpose of raising substances into vapour, receivers become necessary for their condensation. Receivers are vessels which perform a cooling as well as a retaining office, and are as variable in their kinds as retorts. Sometimes a simple tube is used, at others flasks, globes, and bottles ; these receive the vapours, condense them, and retain the resulting fluid. On other occasions the receiving apparatus is more complicated in form ; one part serving to condense the vapours, and another to contain the products. These varieties and the methods of managing them will be best illustrated by a few simple examples.

447. The simplest arrangement of retort and receiver is to introduce the beak of the former, when charged, into the mouth of the latter, which may be a flask or globe (372), and then proceed to distil. This is an arrangement readily made, and in constant use in experiments upon inexact quantities. The receiver is frequently retained sufficiently cold by the air to condense the vapours ; or, if it be desirable to increase the refrigerating power, it may easily be done by putting the globe into a basin of cold water.



During the distillation the globe may be turned now and then, to bring different parts into contact with the water in the basin; and if at times it becomes quickly heated from a rapid production of vapour, the cooling power may be increased by covering the upper surface with a doubled piece of filtering paper, and pouring a little water, at intervals, over it. Water, and most substances not less volatile than it, may in this way be distilled in ordinary experiments, with very little loss. Nevertheless, as the vessels are open, and the cooling process is not fitted for the condensation of a sudden or large production of vapour, the arrangement should not be used except in experiments in which the substances remaining in the retort are the same with those which are condensed, or where a little loss of matter is of no consequence.

448. On other occasions, although an open apparatus may be convenient or necessary for the ready substitution of one receiver for another, yet great cooling power may be required. An arrangement requisite for the distillation of sulphurous acid will illustrate some of the means which, either separately or in conjunction, are then advantageously applicable. The retort in which the sulphurous acid is generated, is attached, by a caoutchouc connector (840), with a bent piece of glass tube of the form represented in the



figure, and that again by another caoutchouc connector, with a second bent tube, also figured in the cut. The first tube is to be placed in a glass or other vessel, convenient for holding a frigorific mixture (454); the second is for the purpose of conducting the

gas into the receiver, and is represented as passing into a small stoppered flask. These tubes should be of sufficient diameter to allow of the free passage of all the gas that may be liberated, and the first or cooling tube should be so large as also to retain all the fluid that may be condensed there, and yet allow free passage for the uncondensed gas.

449. The caoutchouc or India-rubber connecting pieces

are easily made, and are of such constant use in attaching tubes and apparatus for the conveyance of vapours and gases, that a number of them, from an inch to two inches long, and from a quarter to half an inch in diameter, should be kept ready in a box or drawer (1122). They are most easily made of sheet caoutchouc, which is about the tenth or twelfth of an inch thick, and may be had in pieces ten or twelve inches square. A piece of this caoutchouc, about an inch and a half square, is to be slightly warmed till it becomes flexible and soft, and then put round a glass rod or other cylindrical body, rather smaller than the intended tube; the projecting edges are to be pinched together, and when they have slightly adhered, cut through with a pair of very sharp, clean scissors; this will remove the superfluous caoutchouc, will expose perfectly clean surfaces upon each edge, and leave the two edges slightly adhering together. The junction is to be completed by immediately bringing these edges into contact throughout the whole extent of cut surface; which may be done by applying a thumb-nail upon each side the section, and pressing the surfaces together, the glass rod within supporting the caoutchouc, and thus assisting to obtain the desired adhesion. This operation, if neatly performed, will cause the cut surfaces to apply so accurately to each other, that no part of either will appear. When firmly pressed together whilst warm, the adhesion is such that the tube will tear elsewhere as readily as at the junction. The tube should be made so loose that it will easily slip off the glass rod. If the caoutchouc has been stretched to make the edges meet, and the tube consequently fits closely to the rod, it will frequently adhere so tightly as to be difficult of removal; but this may be obviated either by putting a little flour over that surface of the caoutchouc which is to be the inside of the tube, and which prevents its adhesion to the glass; or by wrapping a piece of paper first round the rod; or by using a thin tube instead of a glass rod, and breaking it to pieces when the tube is finished, if it should happen to adhere. Great care is necessary, in using the flour, that none have access to the surfaces to be joined, for

any kind of dirt or extraneous substance prevents the adhesion, and the tube is rendered imperfect. On the other hand, when the tube is finished, and it is desirable to prevent the adhesion from pressure of the sides within, then a little flour, chalk, or other dry powder is very useful.

450. If sheet caoutchouc cannot be obtained, the tube may be made of thin bottle India-rubber. For this purpose, the smallest and thinnest bottles should be chosen, selecting from them, when cut up, only the most straight and uniform pieces that can be obtained. They should first be softened by being placed in a warm situation for some hours and rubbed frequently, or by being placed in hot water for half an hour: then, being dried, they may be formed into tubes. The caoutchouc in bottles is more rigid and stiff, and less adhesive, than that in sheets, and for this reason, greater pressure and more care are generally required in making the joint firm and tight; the tubes will probably require warming two or three times on the rod during the operation of pressing the edges together, and perhaps, also, compression of the joint by a pair of pincers.

451. Although these tubes have been described as cylindrical, yet they are frequently useful of a conical form to connect tubes or apertures of different sizes (843). There is no ordinary agent, except perhaps chlorine and strong nitric and sulphuric acids, which act upon them; hence they are very generally applicable. When tubes are connected by them, as in the present case of sulphurous acid, one of these flexible connectors should be selected of a size near to that of the tube to which it is to be adapted. If small, it easily admits of extension, and is then slipped over the ends and tied with two or three turns of fine twine or coarse thread, which should not be drawn tight, or it will cut the caoutchouc; indeed, when the tube has required a little expansion to make it pass over the glass, it contracts with sufficient force to form a joint impervious to gas at ordinary pressure; very little stress, therefore, upon the thread is sufficient to secure any joint in a perfect manner. If the caoutchouc tube be a little too large, so contractile and manageable is the substance, that tying is quite sufficient to make it tight.

452. Where the object, as in the present case, is merely to connect different parts of an apparatus, the ends of the glass tubes should be from the eighth to the fourth of an inch apart within the caoutchouc connectors. This is quite sufficient, in ordinary cases, to allow of that flexibility in complicated glass apparatus which is so valuable as permitting motion and the minute adjustments of one part, without endangering another.

453. The apparatus for a distillation of this kind at low temperatures being thus connected, and ready for an operation, the next step is to apply the necessary means of cooling the parts where condensation is to be effected. For this purpose some ice should be pulverized, the first glass represented in the wood-cut (448) half filled with it, and then nearly filled up with water. For the second glass, a more powerful cooling mixture must be prepared; for this purpose ice and salt should be used, the glass being filled with the mixture to within half an inch of the top.

454. In making this mixture, a little ice should first be put into a mortar, and having been broken small, during which operation the mortar will have cooled considerably, should have about a fourth of its bulk of salt added and rubbed with it: fusion of much of the ice will take place, and a cold of 0° will be produced. After a few minutes this portion is to be thrown away, for, being fluid, it would not long retain its low temperature in a warm atmosphere, and its use should therefore be confined to cooling the mortar and pestle. The operator should now proceed to pound ice and salt together for a mixture to be used in the distillation. The quantity of salt used should be about one-half the weight of the ice, or nearly one-third its bulk; this is far more than the water from the ice can dissolve, but the excess is necessary to insure, with facility, the cold of 0° , as long as ice continues undissolved. The pulverization of the ice, and its mixture with the salt, should not be discontinued as soon as the temperature in the mortar is at 0° , but continued, consistently with a quick operation, until the ice is as small as possible; otherwise, after being put into the glass, and standing for a time, a quantity of liquid will form,

the solid salt will sink, the lumps of ice float, and it will be found difficult by stirring to keep the temperature down to 0° ; whereas, if the ice be in fine particles, when, from the production of brine, a partial separation does take place, very little stirring will be sufficient to keep the temperature at 0° , until nearly all the ice be dissolved. The state of the mixture in the mortar is most advantageous when, with a due proportion of salt, it contains most *solid ice* in a small state.

455. Neither a cold mixture, nor ice and water, should be poured suddenly into a glass at common temperatures: it is safer to cool the glasses previously by putting a few pieces of ice into them, and then, upon removing the ice, to introduce the mixtures. The receivers, which are to be placed in the cooling mixture, should also have their temperatures lowered gradually; this is easily effected by allowing them to remain for a few moments among the loose ice.

456. It may be observed that so long as the first glass contains ice mixed with water, the water will be at 32° or nearly so; and in the second glass, if stirred now and then, the temperature of the whole will remain nearly at 0° , so long as both ice and salt in any quantity remain in the solid state. But if the operation should continue until nearly the whole of the ice in both is dissolved, it is better not to wait till all has disappeared, but, whilst a fifth or sixth part remains, to prepare a fresh mixture for the second glass, and, removing part of the water from the first, to replace it by ice.

457. These cooling mixtures receive heat so rapidly from the atmosphere, especially in summer, as often to have their power exhausted in one-half or one-third the time during which they would remain effectual if such influence were prevented. When operations, therefore, of any kind in which refrigerating mixtures are used, are continued for a long time, it is highly advantageous to prevent the effect as much as possible, that the trouble, expense, and loss of time attendant upon the frequent renewal, may be avoided. All that is necessary is to hinder the access of air, either by wrapping a dry flannel or cloth round the sides of the cooling vessel, or even a large sheet of paper three or four times

loosely round it, so as to form a cylinder, which is to be tied with packthread (1343). This case should rest upon the table beneath, so as to prevent as much as possible the passage of air at the bottom: not that small apertures need be attended to, but free way for a descending current should not be permitted. The tops of the vessels may be covered temporarily by laying on them loosely a card or a couple of cards with notches, to receive the tubes. Small portions of freezing mixtures may in this way be preserved for hours together, at 0° , in the middle of summer. In hot weather, merely putting the glass containing the refrigerating mixture into a glass jar is very useful, for the latter retains a bath of cold air around the former which retards the alteration of temperature very greatly. The jar should be covered with a card, or paper, to keep the atmosphere within in a quiescent state.

458. Having made the proper preparatory arrangements, the distillation of the sulphurous acid may be commenced and carried on. The gas being liberated from any of the usual materials in the retort, passes first through the bent tube retained at a temperature of 32° by the ice and water. Several advantages result from the use of this vessel. In the first place, water brought over with the gas is in part condensed and retained; in the second, the temperature of the gas is reduced to 32° , and consequently its condensation more easily effected in the receiver; in the third, being evolved in a warm state, much of the heat which must necessarily be abstracted from it before it will assume the liquid form, is removed here, where the refrigerating agent (ice and water) is easily restored, and consequently less of the cooling power of the mixture in the second glass is required for its ultimate condensation, and the latter remains effectual for a longer time.

459. Leaving the first part of the condensing apparatus, the gas travels on to and enters the receiver. Being heavy, it soon displaces the air; and then, coming in its unmixed state against the sides of the receiver at 0° , it is condensed, and assumes the liquid form. This condensation, as the student will know from his scientific sources of

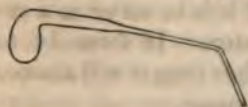
chemical knowledge, evolves heat, and will consequently tend to raise the temperature of the mixture around the receiver: in this, and in all similar operations, a thermometer should therefore be immersed in the mixture, to indicate whether its temperature is such as it ought to be.

460. It will be found advisable, in all cases where the substance distilled is so volatile as to require these low temperatures for its condensation, to collect it in small receivers; not only that it may soon come into contact with their cold sides during condensation, but also that it may be in convenient portions for operating with in experimental investigations (924, 929). The vessel in which the body is condensed should generally be that in which it is afterwards preserved; and as, in most experiments, the quantity in one vessel will (unless with peculiar management) be used at once, it is better, in the first instance, to receive the substance in such small portions as, being sufficient for each time, shall leave no overplus; so that waste may be avoided. Operating in this way, it will be necessary to change the receivers frequently: this is easily done in consequence of the flexibility of the arrangements. Those receivers which are to replace in succession such as are sufficiently full, should be preserved cool by a mixture in a separate glass.

461. The receivers may in many cases be small flasks or stoppered bottles, but the latter are generally so thick at the bottom as to fly to pieces when one of them containing such a volatile body as sulphurous acid is opened, in consequence of the sudden cold produced by its evaporation. Very useful receivers for these purposes will be described in Sect. xvi.

462. The various circumstances necessary to an effectual arrangement for a distillation of this kind have now been described minutely. It will be unnecessary to point out the applicability of parts only of the arrangements—their uses in the present instance will be so evident as to indicate their sufficiency in other cases; and though a particular form of the tubes has been described, yet the parts may easily be altered and arranged at pleasure.

463. There is, however, one point with respect to the retort worth suggesting, as it will often be found useful. It is the advantage derived from an elongation of the neck of the retort itself, by softening it at the table blow-pipe (1179, 1176), and drawing it out sometimes almost to a capillary tube; and also by bending it in different directions upwards or downwards. Opportunities are thus obtained of delivering the products of

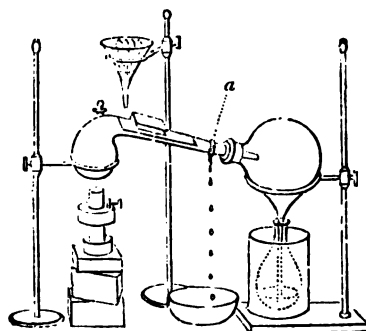


the distillation through minute apertures, and upon particular spots, in a very advantageous manner. Similar opportunities of course exist with respect to the tube which terminates the distillatory apparatus (448).

464. In the apparatus and arrangements hitherto described, the passage is free from the retort to the air, and in the distillation of sulphurous acid it will generally be found that much of the substance escapes and is lost. In some operations this is carefully to be avoided: thus in the distillation of wine for the purpose of ascertaining the quantity of alcohol it contains, if vapour be lost, alcohol is lost, and the results are inaccurate. In other cases, as in the preparation of concentrated hydrocyanic acid, though the exact quantity of the product is not required, yet being valuable and also deleterious to the lungs, it is desirable to prevent loss as much as possible. Some arrangements will, therefore, now be described tending to secure all the results, and allowing at the same time of the introduction and illustration of other contrivances.

465. Let us suppose the object were to distil some wine for the purpose, as already intimated, of separating the alcohol it contains from the other principles, that its quantity may be accurately estimated; and let us consider it as having been introduced into a tubulated retort with the precautions already described to prevent soiling the neck (437), and with the introduction also of some clipped platinum foil and two or three pieces of cork which may have little pieces of platinum foil stuck into them (441). The wood-cut represents this retort connected with a quilled receiver which is to assist in the condensation, and of which the quill descends into

a flask which is to receive the distilled spirit. The retort should have a neck of comparatively considerable length; for, by a contrivance to be described, a large portion of it is to serve as a refrigerator. If from 14 to 18 inches long it will answer the purpose.



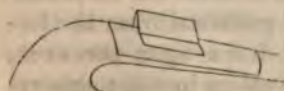
466. The retort and receiver are connected by a cork, and it is better that

the neck of the retort and the opening of the receiver should be of very different dimensions, than that they should nearly fit. If the aperture of the receiver be about two inches in diameter, it will be large enough to admit the necks of most retorts. A bung of good cork (1331), chosen of such size that it will fit tightly into the aperture of the receiver, should be pierced as before described (67), the hole being of such dimension, that, when the neck of the retort is thrust tightly into it and then connected with the receiver, the beak may pass in about as far as is represented in the wood-cut. If the cork be good, well cut, and the hole neatly made, this junction will be air-tight, or nearly so, and may be made quite secure by drawing a slip of moist bladder tightly round it several times, and tying it on by a few turns of twine. Before the cork is introduced it should be pressed or hammered softly, so as to render it soft and elastic.

467. The flask should be of such a size as to permit the quill of the receiver to approach close to, or to touch the bottom. It should be immersed in a jar of water, and a few pieces of ice should be put into the jar and allowed to float on the surface, for the purpose of keeping the temperature at or below 40°. The flask, whilst empty, will be so much buoyed up by the water, as to press against the end of the quill if its aperture be large enough to admit the latter so far through it; but this should be prevented, as it endangers the bottom of the flask. A little slip or wedge of wood introduced between the quill and the flask

at the neck, will retain the latter, so that the end of the quill may be about a quarter of an inch from the bottom. So much pure water should be put into the flask as to rise just high enough to close the aperture of the quill.

468. Both receiver and flask are in this way adapted for refrigeration; but the intention is not to effect the principal condensation there, but to insure the retention of all the spirit by liquefying such portions as may pass the neck, where the condensation is principally to be effected in the manner now to be described. A little loose tow should be drawn out into a sliver, wetted, and wrapped twice round the neck of the retort, the ends being so long that they may be twisted together beneath, with a few threads of the tow pulled out from the part that has already passed round, and hang down for about four or five inches in length. The ring of tow which thus surrounds the neck should be placed about half an inch or an inch above the junction before mentioned, as at *a* (465); it should be moderately tight round the glass, and should be carefully separated from the bladder or cork beyond, so as to have no part in contact with it, touching indeed nothing but the neck. A single piece of filtering paper should then be selected, long enough to reach from about half an inch above the tow to the part where the neck begins to turn and blend with the body of the retort, and wide enough to go two-thirds or nearly the whole way round the neck: it should not pass



quite round, as it then does not apply itself so readily in the wet and dry state to the glass. Being laid on the neck of the retort and moistened, it will adapt itself to the glass, adhere closely to it, and will serve the office of conveying water to every part to which it is applied; and it should be observed that all parts of this surface is of such inclination; that the fluid condensed within will run into the receiver, and not return again to the body of the retort.

469. The water is to be supplied to this paper from a filter in a funnel placed above (532, &c.), in such a position that the drops shall have to fall about half an inch or an inch, which assists in spreading the water over the paper,

and also shall descend upon the paper a little way from its upper extremity. If they fall on to its edge, or on to the glass, a few particles may splash upon the hotter parts of the retort, or portions may run down its outside. Water should be put into the filter in such quantity, that it may descend sometimes in a small stream, and sometimes in rapid drops: it will wet the paper and the glass under it, and running down to the tow, will there descend and be caught in a basin placed beneath, not a particle passing beyond the tow to endanger the introduction of any portion into the flask, either by soaking through the bladder, or by running down the outside of the receiver and the quill.

470. Still, however, the water, in its tendency to descend, will not wet all parts of the paper fully and equally if it be of much extent; and the upper surface of the lower end incurs

the risk of being sometimes dry. This is avoided,



and the paper freely wetted in all parts by the use of another piece of filtering paper folded as here drawn. Being placed with its two lower edges upon a moist surface, it will absorb water, the two sides or flaps will bend down, and, accommodating themselves to the wet surface beneath, will adhere to it, and the central part will stand up in a ridge, leaving an acute angled space between it and the moistened surface. Being, therefore, applied to the neck of the retort, it adheres, is stationed there like a saddle, and answers the purpose of a channel for the water. Its proportions and position may be gathered from the former wood-cuts. The water which drops upon the neck, just above its upper opening, partly enters into the channel there formed; and whilst about a third of it is carried through, and delivered at the lower end of the channel over the upper surface of the neck, the rest flows out along the sides of the saddle, and being distributed all over the paper adhering to the glass, keeps it thoroughly wet and even flowing with moisture.

471. All is now prepared for distillation: heat is to be applied to the retort, and when the upper part becomes warm, the filter must be supplied with water, so that the condensing arrangement on the neck may be constantly and

fully moistened. Upon commencing ebullition, the temperature of the neck will rise, water will rapidly evaporate from the moist paper, and care must be taken that the supply be sufficient, not merely to keep the paper fully wet, notwithstanding the evaporation, but to have a surplus running off in a small stream from the tow. The distillation should not be hurried, and the quilled receiver should never be more than warm about the part where the retort is inserted. If it become hot, or if vapour enters it visibly from the retort, rising and causing rapid condensation over the whole of the upper surface and elevating its temperature, then either more water must be suffered to fall upon the neck, or if that be fully moistened, and still does not effect a sufficient condensation, the heat must be diminished.

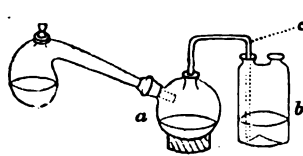
472. The tightness of the junction between the retort and receiver will be rendered evident upon the application of heat, by the expansion of the air within, and its passage from the bottom of the receiver beak in bubbles through the water. This will continue until much of the air is expelled, and the retort and part of the neck is filled with vapour. As the distillation proceeds, the condensed liquid will flow down to the water in the flask and mix with it. The first portion which rises is the most volatile; but, combining with the water, and being diluted by it, and its temperature being reduced at the same time to about 40° , no appreciable portion will escape. As the quantity of fluid increases, the quill will be more deeply immersed, but this is of no consequence: the fluid will rise and fall in it, and occasionally when the heat slackens, or when fresh water has been put into the filter, the condensation within may be such that nearly all the contents in the flask may pass up into the globe, and even air enter it. This is of no importance; there is abundant space in the globe for the liquid, so that it cannot be drawn back into the retort, and it even has the advantage of cooling that vessel; in a few minutes the expansion within will cause it again to return into the flask, and probably a portion of the air previously absorbed may now be expelled. When about five-sixths of the contents of the retort have passed over, all the alcohol will

have been separated, and the operation may be concluded: the diluted spirit in the flask or flasks, if a second has been required, being reserved for the prosecution of the intended experiments.

473. It is sometimes necessary in distillatory processes to keep a part of the neck hot, for the purpose of preventing the condensation of the vapours there. This is readily effected by wrapping it in two or three folds of dry flannel or cloth, or even paper, the envelope being loose and tied with twine.

474. The refrigerating arrangement (468), although described of such a size as to occupy nearly the whole of the neck, may vary in extent and form, and be applied to other apparatus, as well as the neck of a glass retort.

475. In other cases of distillation, it may be required to condense the liquid products out of contact with other substances, and yet to retain the uncondensed portions, so as to pass them through water, or, if gaseous, to conduct them to their proper receptacles. The accompanying figure will illustrate a case of this kind, which may be supposed to be a distillation of nitric acid from nitre and sulphuric acid. The retort containing the charge is connected with a globular receiver of the form *a*, from which a bent tube proceeds,



and passes into the Woulfe's bottle *b* (843). The junctions between the receiver and the retort and tube are best made by ground glass joints; but if that

plan cannot be adopted, other means must be resorted to. Good pierced corks will answer the purpose, the junction being made vapour-tight, either by some glazier's putty put over it, or a paste of linseed meal (1031), or a little plaster of Paris; and where the neck or tube nearly fits the aperture, it may be made tight without a cork by plaster of Paris alone; the open space being first closed by rather a thick paste of it, and the joint made smooth and tight outside by a thinner portion (1108). The plaster will resist the action of the acid vapours; cork and other substances will be somewhat acted upon, but with care will cause no

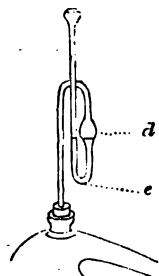
injury to the results. If bodies, not corrosive, are distilled in this way, these precautions, as to the nature of the closing substances, are not necessary (Sect. xviii).

476. The receiver *a*, and the bottle *b* may, one or both, be cooled, according to the temperature produced by the vapour, being for that purpose immersed in jars or pans of water; the neck of the retort may, occasionally, be cooled as before by paper and the filter (468). Caution must be used in applying that method however to such substances, as, from the high temperature at which they boil, produce very hot vapours, lest the differences of temperature be so great as to break the glass. Bodies, not more fixed than water, may, when distilled in glass retorts, have that process applied; but, when substances requiring higher temperatures, for example, nitric acid or oil of turpentine, are distilled, then hot water should be put into the filter instead of cold, or the refrigeration should be carried on further down the neck, where the contents are of a lower temperature.

477. At the commencement of the operation, it is supposed that the receiver *a* is clean and dry, and that the bottle *b* contains water enough to cover the end of the tube. In the distillation, therefore, any product condensed in the neck of the retort, or in the receiver, will be retained in an undiluted and unmixed state; but the portions, which, from their particular nature, or the comparatively high temperature of those parts, remain uncondensed, will be conducted into the bottle, and their condensation facilitated by the solvent powers of the water, or the still lower temperature which may there be applied. If any gaseous matters are evolved, they may be conducted away by a second tube, and treated as hereafter to be described (746).

478. There are one or two additions now and then required to this and other arrangements, in consequence of occasional peculiar circumstances to which they are subject. It may be observed, that if partial condensation of the vaporous atmosphere in the retort and receiver takes place, the solution in the bottle *b* will be forced back into the receiver *a*, and mix with its contents (475). One method of avoiding

such an effect is by the use of Welter's safety tube. This instrument is figured in the wood-cut, and may be fixed in the tubulature of the retort. Mercury is to be introduced until it fills about one-fourth of the little bulb, and the tube by its side, to the same height; this closes the passage, but admits of a variable column of metal, according to the pressure within the retort and receiver. Whenever there is condensation within, the external air has a tendency to enter by forcing the water up the



tube *c* (in the former wood-cut), and the mercury into the ball *d* (of the present), and will gain entrance where the fluids exert the least pressure. Hence it is necessary to have the height of the tube *c* above the water in the bottle *b*, more than fifteen times that, from the bend of the safety tube at *e*, to the level of the mercury, when nearly the whole of it is in the bulb; for in that case, the air will enter by passing through the mercury in the bulb, and not by forcing the water into the receiver at *a*.

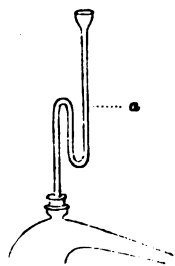
479. Should it be impossible, from some limiting circumstance, to establish this proportion of 1 to 15 or more in the height of the column of mercury and fluid, then, in place of mercury, water may be used in the safety tube, provided that if a little were to enter the retort it would occasion no injury, but then the height from *e* to the top of the safety tube should be two or three times the quantity by which the tube *c* (475) dips into the fluid in the bottle, otherwise the pressure of the gaseous contents may, on some occasions, force a passage out through the safety tube, and derange the regularity of the experiment.

480. It is to be observed, that a few bubbles of air entering by the safety tube, are more effectual in preventing further contraction of the vapours within the retort, than the entrance of the whole of the water by the tube *c* would be. These bubbles come at once into the hottest part of the vessels, are there much expanded, and at the same time actually lessen that tendency of the vapour to condense, which is at the moment threatening the mischief; whilst, on

the contrary, the water on entering would rapidly increase the tendency to condensation, both by cooling the receivers and by its absorbent power over the vapours, with which it would be brought in contact. It will generally be found in such cases, that when one drop of water has entered, the rest will rush violently after it.

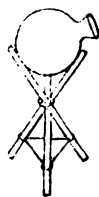
481. Another arrangement of a safety tube may now and then be adopted, but being more applicable to gaseous manipulations will hereafter be described (847).

482. A contrivance something resembling the safety tube just described, is often useful in feeding a retort with fluid during the progress of distillation. For this purpose a piece of tube may be bent into the form of a double syphon, as in the figure, and fixed into the tubulature of the retort.



Acid poured into it will rise in the first two portions to the height of the second bend, and then further additions will flow into the vessel. The part *a* should be of sufficient length to contain a column of fluid, heavy enough to counteract any pressure outwards that may occur within: its length should be at least twice that of the middle portion.

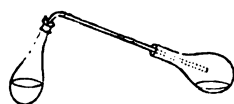
Its upper extremity should be opened out at the blow-pipe table into a funnel form, and the tube should be so large, that the fluid may be poured down without carrying air-bubbles with it. If it be so small that air mixes with the passing fluid, the relative weights of the columns are deranged, and sometimes the acid is thrown back and even out of the apparatus, and at other times is all drawn by syphon action into the retort.



483. A sufficient number of instances have now been adduced, to illustrate the different arrangements that are useful in distillations performed with glass retorts. But little has been said relative to the methods of supporting the different parts in their respective positions. The delineations, and the descriptions relating to flasks (386), retort stands (386), bricks (24), rings (68), wooden blocks, (20), &c. being sufficient for the purpose. When these conve-

niences are wanting, very useful tripods may be made, by tying three sticks together at the middle, and confining them beneath by string, to prevent them from slipping down.

484. In cases of necessity, Florence flasks may often be substituted for retorts in distillation; a neck being formed



of a piece of bent tube, and attached to the flask by a good sound cork, made tight by accurate fitting without bladder or lute. Corks thus circum-

stanced sometimes swell by the heat and moisture, so much as to endanger the neck of the flask, and if it be discovered, by the expansion of the part outside, that such danger is to be apprehended, the cork should be partly withdrawn and in that way relieved.

485. Before leaving the consideration of distillations, which may be performed at temperatures easily borne by glass, there are one or two remarks to be made in addition to those already given. There are some cases in which, although the heat necessary for the operation may be easily sustained by glass retorts, circumstances will make it advisable to prefer retorts of other substances. In the preparation of fluoric acid, a vessel of lead will be superior: glass would then be easily acted upon, and at the same time that the retort would be destroyed, the product obtained would not be pure, but a combination, with part of the vitreous matter. There are some substances which, though sufficiently volatile, are very difficult of distillation in glass vessels. Of such kind are bone oil, Dipple's animal oil, sometimes naphtha, and some of the common essential oils, when free from water. These are distilled with great facility in a tin plate or copper retort, but as they frequently require a high temperature, the vessels should not be soldered, but be either brazed, or the joints lapped over and then made tight by a small quantity of solder.

486. The essential oils are generally distilled with water: they rise in conjunction with its vapour, at a temperature far below that at which they would distil alone. Advantage may be taken of this circumstance in many cases where the

contact of water is of no consequence; and bone oil, naphtha, and other substances of that kind, may be distilled in a similar manner. It is to be remembered, however, on future occasions, that the substances generally retain a small portion of water, which, unless removed, may be injurious in particular experiments.

487. In small distillations, other cooling agencies, besides those mentioned (447, 448, 465), are useful. With this view, alcohol, ether, carburet of sulphur, and even sulphurous acid, are employed; being dropped upon the condensing vessel, they effect their object by rapid evaporation. These are more particularly serviceable in small operations, where the substances are distilled by cooling the receiver, instead of heating the retort. Processes of this kind will be described and illustrated in Section xvi. on *Tube Chemistry*.

488. As a heated tubulated retort cools, it is advisable to loosen the stopper from time to time, lest the differences of contraction, from previous difference of temperature, should cause it to become fixed so tightly that it cannot be removed without risk of breaking the vessel.

489. In operations of distillation requiring temperatures so high that glass would melt, either earthenware or iron retorts must be used, or the glass must be protected and strengthened by an exterior coating of lute (1084, 1093). Notwithstanding the fusibility of glass, and its liability to chemical action at high temperatures, and in a softened state, it is still, when coated, often superior to earthenware, because of the permeability by air of the latter substance when hot, and its great risk of fracture at high temperatures, either during the heating or cooling; and it is often preferable to iron, because, though liable to chemical action, it is generally less so than that metal. For the choice of the lute, and the method of applying it, see Section xviii. *Lutes, Cements, &c.*

Glass retorts should be coated at a leisure time, and several of them kept ready for use in a warm place (16). Their perfect dryness is then secured, and time is allowed for the stopping of any cracks that may have been formed in the coat.

490. When perfectly dry, and prepared for the fire, and charged with the materials to be distilled, they then require to be adjusted and supported in a furnace that they may be heated. They should not be allowed to hang from the neck as is frequently permitted in ordinary distillations, but must be sustained from beneath, that when the glass is red-hot and soft, there may be as little stress or weight to disturb



its form as possible: for the lute is generally so much cracked by the heat, that though it will adhere to the glass and hang together, it gives on the whole very little strength unless supported below; it even,

by its weight, sometimes does more harm than good. A very excellent support, on many occasions, is a small round crucible filled with sand, and placed on the bars of the furnace, the bottom of the retort being allowed to rest upon it. At



other times, a couple of bars of iron, crossing the furnace, are used, and now and then stands, either of wrought or cast-iron, of the form figured, and of different sizes. The upper wood-cut represents the section of a coated glass retort, placed within a crucible furnace (158), and supported on a crucible. The furnace is notched at the side to admit of the passage of the retort neck.

491. Retorts may now be obtained made of either crown or bottle-glass, and bear a much higher heat than those of flint-glass, so that they will bear exposure in their unluted state to the fire, and do service better than a luted flint-glass retort. If luted, they will sustain still higher temperatures. Retorts of Bohemian glass (703) may occasionally be procured.

492. Earthenware retorts are made of very different materials. The ware is sometimes close and compact, like that of Wedgwood, that the vessels may be but little permeable to air; and sometimes more open and coarse, like the red or brown ware, being then less liable to crack in the fire. They should be heated very gradually, and also cooled with the same precautions, if it be desired to save them from fracture; but it is scarcely worth the attempt to use an earthenware retort a second time, because of the difficulty of ascer-

taining the clean state of the inside, and because of the almost inevitable existence of fissures. In some cases earthenware retorts may be rendered tight, *i. e.* impermeable to air, by washing their surfaces with a solution of borax, or rather with a cream of 1 part powdered borax, 2 of finely-pulverized glass, and water. These materials fuze and cover the surface with a glaze, which effectually prevents the passage of air.

493. Earthenware retorts should rarely be put naked into the fire; when luted, as has been directed with regard to glass retorts (489, 1084), a great degree of security beyond what they possess when naked, is afforded. They should be carefully dried before being heated, and if washed with the mixture of powdered borax, glass, and water, previous to the application of the lute, are rendered impermeable to air or vapour.

494. Small iron retorts are more frequently used for the distillation of oxygen and carbonic oxide gases, than for any other purpose. They are usually in the form of bottles having an iron tube fitted to them by a ground joint, which answers the purpose of a neck. By frequent use, this joint oxidizes, scales, and is no longer quite tight; it may then be rendered so by mixing up a little fine lute, as Cornish clay, into a thin paste, with either water or oil, and putting it round the tube before it is thrust into its place: in these cases the retort should be introduced very steadily and carefully into the fire, lest, by shaking, the joint should be loosened. As little of the oiled substance should be allowed to pass within the retort as possible.

495. Distillations with the iron retort are best effected by a coal or coke fire. The table furnace fire (169) answers perfectly well, the tube of the retort being brought out either at the door, or through the rings put on above, in place of the sand-bath (176).

Sublimation.

496. The apparatus for sublimation in the laboratory consists generally of tubes, flasks, retorts, capsules, and crucibles. Those which are adopted in manufactories being

confined to particular operations, are therefore constructed of such materials and form as fit them for their exclusive purposes. The use of tubes in the sublimation of small quantities, will be considered hereafter. (935, &c.) Such substances as are of moderate volatility, like naphthaline, iodine, camphor, &c., may be sublimed in glass retorts; the vessel being heated by a lamp or sand-bath, or small furnace, and the neck introduced into a large globe or flask, for the condensation of the vapours. The flask may either be cooled or not, according to the circumstances of the case, the means being those before described. (447, &c.) Florence flasks are frequently superior to retorts for these purposes, and being placed in an inclined position, their necks may be introduced into receivers, as has been directed with respect to the beak of the retort (447).

497. The alembic is frequently used with advantage in the sublimation of substances of moderate volatility. Its convenience consists in the facility with which the products and residue of the sublimation may be removed. There is nothing peculiar in its use requiring notice.

498. Florence flasks are useful in sublimations, which require a higher temperature than the substances just referred to, such, for instance, as calomel, cinnabar, &c. Being charged with the proper materials, they may then be bedded in the sand-pot (176), and surrounded by the sand to a height more or less above the level of the materials within, according to the volatility of the substance. A red heat may then be applied, and the products condensed in the upper part of the flask; or received into another flask,



having a wide neck; or with the neck cut short and placed over the first. Sometimes a large tube, with its end bent, so as to pass over the neck of the flask, is a very convenient condens-

ing vessel. The joint may be wrapt with dry paper, and tied with twine, the other end of the tube should be drawn out and contracted (1179), so as to enter a globe, in which vapours, not condensed in the tube, may be caught and finally rendered solid.

499. When Florence flasks can be heated in a sand-pot, they do not require luting, but if they are exposed to a naked fire, must then be strengthened by an exterior coat of clay (1084).

500. Some sublimations are most conveniently performed by putting the substance into a basin (369), which is then to be covered with another containing water; the application of heat to the lower causes the evolution of vapours, which are condensed against the bottom of the upper. Such sublimations as can be effected by the heat of an oil lamp are well conducted in this manner. Sometimes small platina capsules (371) are more advantageous. Indigo is best sublimed, after it is bruised, by being put in small quantities into a platina capsule covered by a larger one (371), and the lower heated strongly by a spirit lamp. The upper should be kept at about 212° ; or a little below, by moistening it with a piece of wetted bibulous paper. After some time the sublimed indigo will be found forming a layer of crystals upon the under surface of the upper capsule.

501. Iron and earthen crucibles are useful for the sublimation of bodies that have no action upon them. The crucible may, in the first place, be charged, and after being covered by a large vessel to condense the vapours, heated in a sand-bath; or, being previously heated, it may be set upon a stone or brick, and after the substance is thrown in, it may be covered. Benzoic acid, naphthaline, and other such bodies, may be sublimed from them into proper vessels.

502. The necks of broken retorts are frequently useful for conducting the vapours which rise during the sublimations in crucibles, &c. They are conical, and occasionally so large at the retort end, that they easily cover a small crucible standing in the sand-bath. The sand, if heaped, will often serve sufficiently to close the lower end of this conductor, and the upper, being introduced into a flask or globe, conveys the vapours into them, which are thus removed so far from the source of heat as to be easily condensed.

503. Finally, cast-iron pots (176) are sometimes in use for the purpose of effecting sublimation; but they require to be covered with a head and tube, for the purpose of leading the vapours to a vessel sufficiently large to receive and condense them; or the pot being so set as to have a level surface continued from the edges on all sides, a box or large vessel may be inverted over the whole, and the condensation effected in the space within.

SECTION VIII.

PRECIPITATION.

504. PRECIPITATION is valuable as a mode of separating substances, and consists in changing them from a soluble into an insoluble state. It always depends upon altering the relation of the solvent to the substance it holds in solution; this being effected sometimes by changing the state of the solvent, as when water is added to a solution of resin in alcohol, or alcohol to a solution of gum in water; and at other times by causing a change in the body dissolved, as when sulphuric acid is added to a solution of baryta to precipitate the earth, or ammonia to a solution of iron to precipitate the oxide. It is often practised to render the presence of a substance visible, and forms an essential part of analytical and other processes, as well in the discovery of bodies (912, &c.), as in their separation and estimation. Any substance added to a solution to cause a separation in the solid form of matters present, has received the general name of *precipitant*, and the substance so separated is called a *precipitate*.

505. Many of the vessels useful in the processes of precipitation have been already described, as glasses (368), basins (369), and flint-glass and Florence flasks (372, 373); but there are two kinds which particularly deserve mention here. The one is a small cylindrical glass standing on



a foot, about one inch in diameter and two and a half in height; it is very useful in testing mineral waters and solutions by precipitation, for which reason, two or three dozen of them should be in the laboratory stock. The other is of the kind called Phillips's precipitating glasses. These are of a truncated conical shape, as represented in the wood-cut, and are often peculiarly useful in the management of flocculent precipitates, in consequence of the facility with which they allow the solid matter to fall to the bottom of the liquid. The precipitate, as it descends, meets with no obstruction from the sides of the glass, tending indeed rather to shrink from than adhere to it; the fluid, on the contrary, tends to rise in the space left, and thus in numerous cases great facility of separation is obtained. They should be provided of three or four different sizes, having about the capacity, for instance, of two, four, and eight ounces (119). Jars of this form have already been described (368).

506. When in the progress of investigation it is required to know whether a substance in solution will be precipitated by certain tests, the latter are to be added, and the whole purposely mixed or suffered to become so spontaneously. If immediate separation take place, the question is answered; but if otherwise, the results are not to be thrown away, and the inquiry decided in the negative; but the mixture is to be allowed to stand for some hours, and then again examined. If no appearance of precipitation be produced, a heat is to be applied, approaching to 212° ; perhaps precipitation may occur during the application of this temperature, and if so, the point is ascertained; but if not, the operator must still persist, by allowing the mixture to cool to common temperature, and then observe it for the last time. For want of perseverance of this kind, possible precipitations are often considered as impossible.

507. Very frequently liquids containing precipitates in such small quantities as merely to have an opalescent or slightly milky appearance, are to be examined and perhaps compared with each other in colour, turbidness, &c. In these cases it is often advantageous to examine them by reflected light, as that thrown back by a sheet of white

paper, for which purpose the glasses containing the precipitates may be placed on white paper, or at other times a piece of paper may be held behind them at an angle such as to reflect light from the sky-light or window. The tints and appearances of several glasses in a row are very well compared with each other by such means, and the process is often of value in comparative testing.

508. Precipitations are generally effected by substances with which, from previous experience, they are known to occur; and manipulative instruction merely relates to the best method of obtaining those expected results, and of thus securing the separation of the whole of the substance held in solution, in processes instituted for its purification, or for the analysis of its compounds.

509. It is frequently necessary to add a precipitant to a solution, until no further effect is produced. Upon commencing the addition, it is easy to observe the formation of the precipitate; but when the mixture becomes milky or thick, the student is unable to perceive whether the additions he makes actually cause increased separation, or whether they are useless. As soon as this happens, it is better to desist from adding the precipitant, and, after stirring the whole so as to mix it thoroughly, to allow it to stand a few minutes; a separation of the precipitate from the liquid will take place at the surface, and allow the removal of a small portion of the clean fluid, either by pouring it out into a little glass (397), or by dipping a rod into it, and transferring a drop or two to a glass plate (70). This done, a small quantity of the precipitant is to be added to the liquid so separated, and notice taken whether any precipitate is produced; if not, enough has been added to the large portion; but if a further effect takes place, the portion removed is to be restored to the general mass, the glass plate being washed by the dropping-bottle (402); more of the precipitant is to be added, and the whole again stirred up and examined as before, until it has in this way been ascertained that no further addition will produce any precipitation.

510. If the separation of the precipitate be slow, it is not

necessary at all times to wait till the fluid at the surface be quite clear; for when opalescent, the further effect produced by the precipitant in the trials may often be observed; it is only when approximating to a sufficient addition of the precipitant, that perfect clearness in the portion removed is required. When the precipitate sinks rapidly, it will be unnecessary to remove any portion for trial; for the liquid, being clear, or nearly so, to the depth of an inch or two, may be tested by dipping a glass rod into the precipitant, and bringing it to the surface: the small quantity of the test thus conveyed will show, during its descent through the clear part, whether more is required or not.

511. Sometimes the solution contains so much precipitable matter, that before a sufficiency of the precipitant has been added, the whole is thick, and even pasty. In nearly all such cases, the whole ought to be diluted; for not only is the fluid part in such small quantity, when compared with the solid, as to be inseparable by the usual means, but the mixture cannot be made with such facility as to insure uniformity in every part; without which, uncertainty with respect to the addition of the precipitant will be occasioned. But if, from peculiar circumstances, it is desirable to avoid dilution, a small portion of the mixture must be diluted in a little glass, and tried as before: the quantity of water thus added to the general mass, when the portion tried is returned, will be no object.

512. The precautions just given with regard to the undue addition of the precipitant, only relate to those cases where either an exact equivalent to the substance to be precipitated is required, or the precipitant itself is valuable, or the superfluous addition of it would complicate and burden the solution so as to embarrass future operations. If a peculiar salt of baryta existed in solution, and it were required to obtain the acid pure by precipitating the earth in combination with sulphuric acid, then any excess of the latter, above the exact quantity necessary to neutralize the baryta, would remain in solution and contaminate the peculiar acid: in such a case, therefore, the precautions above described must be used, and it is better, when the precise point required is

nearly attained, to dilute the precipitant (the sulphuric acid in this instance), so that less risk may be incurred of adding too much at once.

513. If the object be merely to save a valuable precipitant, as nitrate of silver when used for muriatic acid, or to keep the remaining solution as free from extraneous substances as possible, then the trouble of very delicate testing, as before described (509), may be of more consequence than the use of a little excess; and in such cases, when near the point, such a quantity may be added as is known somewhat to surpass it. But when the precipitant is cheap, does no harm if added in excess, and when none of the points above mentioned require attention, it is better not to lose time in minute operations, but to add a considerable excess at once: and indeed in many experiments it will be found that this excess is either necessary for the perfect separation of the substance, or advantageous as very much facilitating it. The student who is commencing his experimental operations should in all cases practise the method directed (though without attending to great exactness), until he is so far acquainted with the nature of the ordinary chemical precipitants, such as acids, alkalies, and salts, as to form a tolerably correct notion of the sufficiency or insufficiency of the quantity added by the appearances it produces.

514 Solutions to which precipitants have been added are easily mixed in glasses or small jars, by agitating with the rods or stirrers before mentioned (374); but where they are bulky, and occupy deep vessels, the mixture is better effected by immersing a small glass tube sufficiently long to reach the bottom of the jar, and blowing air down it with the mouth, so as to make it pass through the fluid in bubbles. These being made to ascend through different parts of the solution, the whole soon becomes uniformly mixed. The extreme upper end of the tube should be placed quite within the mouth, and not in contact with the lips, tongue, or any other part; so that nothing but air or aqueous vapour may pass down it.

515. When rods or tubes are used to stir mixtures which contain weighed or valuable substances, the adhering fluid

should be washed off into the vessel by the dropping-bottle (402), that nothing may be lost; or, if required several times, they may in the intervals be placed with their ends in a small glass, and ultimately both glasses and stirrers washed as before (509).

516. Precipitates do not often require heat for their formation or separation, but in particular cases it is very serviceable: basins (369) and flasks (372) are used for the purpose. If a basin is to be used for the application of heat, the precipitate may be thrown down in it; but if a flask is preferable, the precipitation is generally better effected in a glass or jar, and the mixture afterwards transferred to the flask. More command of the fluid, and easier access to it, are obtained in an open than in a closed vessel. The heat of the sand-bath is generally sufficient in these cases.

517. A few commonly-occurring precipitates are affected by peculiar circumstances, which may be usefully pointed out in this place. Chloride of silver, continually produced in the separation of muriatic acid or chlorine by nitrate of silver, has, when abundant, its separation facilitated by agitation. When the liquid containing it is stirred, or poured backwards and forwards from one vessel into another, the chloride adheres, forming heavy flocculi, which, in a few seconds, fall to the bottom, leaving the fluid nearly clear; whereas, without such agitation, it would require from half an hour to two or three hours to produce an equal effect. It falls also more readily when an excess of the nitrate of silver, or of nitric acid, is present; for which reason these substances may occasionally be added with advantage. Heat assists its separation.

518. The separation of sulphate of baryta from the fluid containing it is very much facilitated by the addition of a little nitric acid in excess where it can be permitted, and also by heat. The two together are highly useful in many analytical processes.

519. Prussian blue, or rather the blue ferro-prussiate of iron, constantly produced in testing for iron, falls much more readily in solutions containing a considerable proportion of

salts or uncombined acids, than in such as are nearly free from them; and for this reason the addition of a little muriatic acid is often advantageous. When recently precipitated, this substance is soluble in pure water.

520. The oxide of tin, formed by the action of nitric acid and tin, can hardly be washed with pure water, because of its suspension; but a little common salt added causes it to separate easily, and may be used in cases where it does or can do no injury.

521. Carbonate of lime, when thrown down from a solution by an alkaline carbonate, has a loose bulky form, which in the course of a short time alters, and the substance becomes a fine gritty powder, rapidly settling to the bottom of the supernatant fluid. This change, which is advantageous to the separation of the precipitate, is facilitated by the application of heat. The solution from which the lime is to be precipitated as a carbonate should not have much acid in excess, for then much carbonic acid is evolved upon adding the precipitant, and, if cold, much carbonate of lime at first remains in solution. The application of heat causes the separation of this portion, but then a large part of it adheres as a crust to the vessel, and occasions trouble in its accurate separation. For this reason it is generally better to add alkali in the first place to neutralize the excess of acid, and then to add the carbonate. Ammonia and the carbonate of ammonia are the substances generally preferred for the purpose.

522. Some of the metals are now and then precipitated from their solutions in the metallic state by other metals. Thus silver is thrown down by copper, copper by iron, lead by zinc, &c. In these cases it is best to retain the solution in an acid state by the addition of a little excess of the same acid as that with which the metal is combined. Silver is generally precipitated from its solution in nitric acid. The excess of nitric acid increases the rapidity of action, in consequence of the electrical effect which occurs as soon as any silver is precipitated, and at the same time tends to prevent any precipitation of copper on the silver, or any separation of oxide of copper. Copper is best precipitated by iron

from its solution in sulphuric acid. The excess of that acid has scarcely any action on the copper once precipitated, and very effectually retains all the iron in solution. Lead is readily precipitated by zinc from any of its soluble salts: the excess of acid is not so necessary in this case; but if the solution be weak, nitric or acetic acid is still advantageous.

523. Dr. Wollaston has devised a very beautiful method of precipitating one metal by another, or rather, by two others combined into a voltaic circuit. This process will be described in Section xvii., on Electricity (1066).

SECTION IX.

FILTRATION, DECONTANTATION, WASHING, SEPARATION OF FLUIDS.

524. FILTRATION is a process purely mechanical. From its nature it can only be effected where the substances to be separated are such as will not dissolve each other; and in almost all cases it is requisite that one of them be in the fluid, and the other in the solid state. It has the advantage of requiring no chemical change in the bodies to which it is applicable. It is of extensive service in chemical research, and is often supplementary to precipitation.

525. Filtration is a process analogous in its nature to sifting, and is performed by putting the mixed substances into a vessel sufficiently porous to admit the passage of one substance, but close enough to retain the other. As before mentioned, the substances to be separated are usually fluids and solids; hence bodies permeable to fluids are those required for the filter. Unsized paper, cloth, flannel, tow, sponge, sand, pulverized glass, flints, porous stones, earthenware, and many other substances, are used on different occasions; but the first is almost exclusively used in the laboratory, a few of the others now and then being resorted to only on particular occasions.

526. Funnels are continually necessary to support the

paper through which filtration is to take place. The ordinary funnels required in the laboratory for the passage of fluids answer the purpose very well, and they are of use for supporting filters, when, from their necks being broken off, they are otherwise unserviceable. They may be either of glass or good earthenware; those of glass are to be preferred, because the progress of the filtration and the state of the filter can be better ascertained in them. Metal funnels should not be allowed in the laboratory. No other glass vessels than the precipitating and test glasses (505), and the jars (368), already described, are required. Stirrers will be necessary; and the platina spatula, the platina-bladed pocket-knife (62), and sometimes other spatulas, are very useful in moving precipitates.

527. The funnels containing filters may frequently be supported by the glass or jar intended to receive the filtered fluid, and at other times by the rings of retort stands. But notwithstanding these facilities, so frequently is the operation required, that a laboratory should be supplied with at least one filtering stand of considerable size (12). The end



of such a stand is represented in the woodcut. It should be 15 inches wide, 3 or 4 feet long, and have an interval between the bottom and top of 12 inches. The top should have a number of round holes made in it at intervals of 6 inches, differing in diameter from $1\frac{1}{2}$ to 3 inches; two or three small ones of half an inch or an inch in diameter being intermixed. The whole should be well made and firm, so as to support considerable weights; the top having frequently to answer the purpose of a table, and to sustain jars full of solutions, as well as to bear funnels and filters.

528. It is no easy matter for the chemist to obtain unobjectionable filtering paper; and yet it is of such importance in reference to the duties it has to perform, that he should not spare pains to procure the best possible. It should be so porous as to admit the free and ready passage of fluids; so close as to retain the finest solid particles; so strong as to bear the weight of a considerable quantity of fluid; and so

pure as to give nothing to the solution, or, if heated with the substance retained upon it, to occasion no mixture of ashes. Some chemists use plate-paper, *i. e.* the paper of copper-plate printers. It is very porous, and yet there are few precipitates that will pass through it; at the same time it is often tender, generally yields a considerable quantity of ashes when burnt, and is inapplicable for minute filters when very small quantities of fluid only are to be worked upon, because of its thickness and consequent waste of the portion of solution imbibed by it.

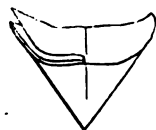
529. It is amongst the thinner varieties of unsized paper, or white blotting-paper, kept by some of the large stationers, that the chemist will probably find the kind best suited to his purpose. It should be so strong, that a single filter of it, capacious enough to hold a pint of water, should not break with that quantity, even though some degree of agitation be given to the funnel containing it. Its porosity, that is to say, its comparative freedom from size (for all is sized in a slight degree), may be judged of by holding it to the tongue, and observing how it absorbs moisture; and by a cautious pull its strength may be ascertained whilst in such moistened state. The student who is unused to the examination of papers, will, however, better judge of its capability of allowing fluid to pass, by actual trial with water; a pint filter, filled with clean water, should allow the fluid to run in a regular stream.

530. The best method of judging of the purity of paper is to burn it and examine its ashes: the fewer it yields, the better it is adapted for filters. A demy sheet should not yield more than one and a half or two grains of ashes altogether. If it contains more, their solubility or insolubility should be observed, that the student may be aware of the impurities that may probably be imparted to solutions in very delicate experiments. In minute cases of investigation, sulphuric acid may frequently be traced to the sulphate of lime existing in the filtering paper.

Filtering paper should be cut ready for use into different sizes: a demy paper furnishes useful sizes for filters, when the sheet is separated into four, or six, or nine parts; and

parcels of each of these sizes being prepared, they should have a string passed through the corners, and be preserved for use in a clean place. This previous arrangement of the paper is very convenient, as readily supplying the sizes that will be wanted, and in preventing the waste that would occur by carelessly tearing up a sheet each time a filter is required.

531. On preparing a filter, the piece of paper should be first examined, by looking through it against the light, to ascertain that it is free from holes. The simplest filter is made by folding the paper twice in opposite directions, in such manner as to bring the four corners together, and by



opening one corner from the other three, so as to produce an irregular conical cavity. Such a filter being put into a funnel, and then filled with water, will immediately permit its passage: but from the similarity of form between the filter and the funnel, and the close adhesion of the former to the latter over by far the greater part of its surface, considerable obstruction is opposed to the passage of the fluid, and the operation is retarded. For this reason different contrivances have been recommended, to separate the filter here and there from the funnel, and allow passages for the fluid. Lavoisier recommended small glass rods put into the funnel before the filter is introduced, so as to lie down and against the sides. Straws are used in a similar way, and they certainly open channels in their immediate neighbourhood, by which the fluid may flow. By other chemists, ribbed funnels are recommended; but it is difficult to find a funnel so deeply ribbed as to support the paper in such a manner that it shall not touch the glass in every part; and if they do not perform this, they are of no use.

532. The best expedient by far is, to fold the filter in such a manner that ribs may exist in the paper itself; and this may be done, so as not only to allow numerous free passages for the fluid between the filter and the glass, but also to allow of ready transmission through its whole surface, and not of one-half only and even that imperfectly, as in the

former case (531). For this purpose, the paper is first to be doubled, and in this state is again to be folded in half, each half folded into quarters, and each quarter into eighths, the folds being all on the same side, and radiating at equal distances from the middle of the folded edge to the other edges. The wood-cut represents the *doubled* paper thus



divided into eight parts. Each eighth is now to be divided into half by folds in the opposite direction, but in lines still originating at the same centre, which makes the

doubled piece resemble a child's paper fan, both when closed and when a little open; it is represented by the accompanying figure.



Whilst in this state, the projecting corners should be taken off by a knife; folding the whole up tight like a closed fan, and making the section at about *a*. Being now allowed to expand a little, the originally doubled sides are to be separated from each

other for the first time, but without disturbing the angles or bending the ridges or ribs formed in them. The separation is easily commenced by blowing sharply upon the cut edge. Having opened the filter sufficiently to separate the cut edges from each other, it will be found that the paper is equally divided into parts forming alternate external and re-entering angles, except at the two edges *b b*, where two external angles come together. Here the intervening portion of paper between the two contiguous external angles should be folded, by bringing the latter together and creasing the paper down, so as to form a re-entering angle between them: this should be done at both places. Then opening



the paper sufficiently to bring the bottom into proper shape, by thrusting out the part which is convex within, so as to make it project externally, the filter is completed, and, being put into a funnel, is ready for use. Its appearance, when perfectly formed, is represented by the accompanying wood-cut.

533. It is necessary, in making these filters, that the folds be not continued to the point, but that they should

strip, about half an inch short of it (see the last figure), for if completed to the bottom, the frequent action of the fingers in folding will so far break down and destroy the texture of that part, that a hole probably will appear before the filter is finished; or if not, it will be so weakened as to be unable to bear a quantity of fluid without breaking. Hence that part of the filter will, during the folding, assume a concave form; and the regularity of the folds, which by practice may be easily attained, must be strictly attended to in the upper part, but may be dispensed with at the lower. When opened out, therefore, for the completion of that part, before the filter is put into the funnel, all that will be required is to push that side of the bottom outwards which is convex inwards, doing it so carefully as to cause no injury. The folds of the filter should be distinct and sharp—an effect which should be obtained by a single decisive pressure, and not by much fingering. No wrinkle or mark should appear in a well-made filter except the folds described, and the portion of paper between the folds should be as stiff as when first taken up. The filter should be handled lightly during the whole of the operation, and never be opened out more than is represented in the last figure. It is best to keep the folds as close, and the whole filter as compact, as possible; dropping it loosely into the funnel, and permitting the fluid poured in to do the office of opening it out. It should be so regularly made, that, when thus expanded by the fluid, the external angles of the folds should touch the glass at nearly equal distances from each other, except at two opposite places where smaller divisions exist; and unless a large quantity of fluid be present, the angles at the upper part should remain almost as sharp when the liquid is introduced as they were before. Below, they gradually pass into the rounded portion forming the centre or bottom of the filter, which will be about the size of a sixpence or shilling, according to the dimension of the funnel in that part. These filters leave such free space between themselves and the glass as to admit of the passage of fluid to a far greater extent than is necessary; and no obstruction being placed against the external surface of the paper, the

whole acts in the filtration, and that in the most favourable manner.

534. Of these two kinds of filters, which may be distinguished as the *plain* and the *folded*, sometimes the one and sometimes the other is preferable. When the object is to cleanse and purify the fluid, that being the valuable part, it is most rapidly and effectually attained by a folded filter; but when the precipitate is the part required to be taken care of, it is generally desirable not to spread it over the irregular and extensive surface of such a filter, but, by using a plain one, to retain it on a surface of only half the extent. It is then likewise of such uniform thickness in every part, as best to admit of the operation of washing, by having successive portions of water passed through it; and when the filter is opened out, the precipitate is delivered in one continuous portion, and not divided into many parts, as happens with the folded filter.

535. When a single filter is judged too weak to hold the mass of fluid it is required to sustain, a double one should be used. If the filter is to be a folded one, then a double thickness of paper is to be taken; but if plain filters are used, the two should be made separately, and put one into the other, in such a manner that the three thicknesses of the one may come against the single thickness of the other. Occasionally it is proper to strengthen the bottom of the filter, which, not being supported by the glass, has to support the greatest column of fluid, but not so as to obstruct the upper part, where a filtration as free as possible is required. In such a case a smaller filter is to be added to the exterior of the large one, so that it may not interfere with the precipitate within, when it is necessary to remove it from the paper.

536. When the substance collected upon a filter is such that heat can do it no harm, and that therefore it is resolved to burn the filter for the sake of procuring all the substance, then use a double filter, the inner one on which the precipitate is disposed being of India-paper, or filtering paper, which being very pure (530), is still weak, and cannot alone bear the weight of filtering matter.

537. The filter and funnel being ready, and placed on the stand in one of the holes before mentioned (527), over a glass ready to receive the liquid, the mixture to be filtered is to be introduced. It should not be poured from a great height, nor upon the middle of the filter, but down the side, the force of its descent being diminished as much as possible by good management, lest it break a hole through the paper: for the same reason it is better to pour it down the rod (369). If the first portions of fluid which pass be not clear, they should be returned into the filter, and a second glass be placed beneath: the solid matter in the liquid to be filtered will soon, by adhering against the paper, cause clear filtration, except perhaps in one or two particular cases, as with precipitated oxide of tin, &c., on which occasions a double thickness of paper must be used. On changing the vessels beneath the filter, for the removal of the clear solution, it should be done so that no drop be lost. By inclining the empty vessel, its edge may be brought under the funnel before the full one is removed; and in no case should a vessel be left under the filter, in which there is not sufficient room for the contents of the latter if it should break. Such an accident ought not to occur, but ought always to be provided against.

538. Supposing a precipitated substance is to be filtered from the solution containing it, and then washed, the mixture may be poured in all at once, or added successively. In the former case, as the fluid passes through, the precipitate forms a soft mass lying upon the paper, but hollow in the middle; in the latter, this hollow nearly disappears, from the successive portions of solid matter added. The first state is the most advantageous for the operation of washing, when it is necessary for the removal of the portion of solution retained by the mass on the filter. For this purpose the vacant space should be filled with water, that it may pass through and displace the solution; and this should be done before the part within has drained to the utmost, and whilst it is still soft and bulky, for the water then finds easier access to all its parts. This water having passed, a second and third portion should be added, and the washing

thus repeated, until, by testing the liquid which passes, it is found to be perfectly pure, or to contain so little matter as to render the rest unimportant.

539. When a precipitate is soft and close in consistency, it is often of use to retain the washing water on it, so as to penetrate and remove the soluble matter. Then the bottom of the funnel should be closed for two, three, or more hours, to retain the water on the precipitate, and when, after removing the cork, that portion has filtered through, the next may be treated also in the same way.

540. Sometimes the mass, though light, is adhesive: it may then very advantageously be stirred up with the added water, but great care must be taken that the filter be not broken in the operation. The top of a quill feather may be used for the purpose. At other times as much fluid as possible having passed through, the filter with its contents may be put into a fresh portion of water, the paper removed, and the precipitate being stirred up with the water, the whole may be put upon a new filter. These processes are applicable when a quantity either of the substance in solution or of the precipitate, being required in a pure state, it is desirable to avoid loss as much as possible, without being particularly accurate. The student should understand, that when a precipitate in its moist state occupies a large portion of the space within a filter, it is impossible, except in very long periods of time, to wash it perfectly merely by passing water through it, because of the greater facility of passage which the water will find in one direction rather than another. When the precipitate forms but a thin layer, or when it can be completely stirred up from the bottom by a jet of water (403, 546) or a feather, it may be well and perfectly washed.

541. It is advisable in all cases of washing in filters, where accuracy is necessary, to make the filter of such a size as to drop entirely within the funnel, and to cover the latter with a clean basin. This protects the upper moistened parts of the filter from evaporation, which would cause the slow but continual ascent of portions of the fluid from below, and consequently a deposit of the soluble substance there. In

slow filtrations a considerable quantity of the substance in solution would be thus accumulated in the upper part of the filter, instead of being washed away.

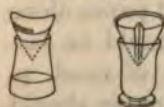
542. It is necessary, in certain cases, first to moisten the filter with water. When aqueous solutions of vegetable matter, which are thick and adhesive, are to be cleansed by this process, the filter should be thus prepared. The advantage will be found very considerable with solutions of sugar. In the filtration of alcoholic vegetable solutions, the filter should always be previously moistened with pure alcohol. Fixed or essential oils, or naphtha, and similar bodies, in mixture with water or aqueous solutions, in which they are not soluble, may be separated from the latter by a paper filter, previously moistened with pure water. In some few cases the other substance may be made to separate by passing through the paper, the filter having been previously imbued with a portion of it in a state of purity.

543. Sometimes hot filtrations are to be performed. Oils filter better hot than cold: tallow and cocoa-nut oil may be passed through paper when hot; and many solutions must be filtered at high temperatures, because of the greater solubility of the ingredients under those circumstances. In these cases the fluids should be heated in a flask or basin before they are poured into the filters; and the filter funnels being placed in the glasses or jars, and, after the fluid is poured in, covered over with a basin or glass plate, the whole should be enveloped in a piece of flannel or a dry cloth. If, from the length of the operation or other causes, the flannel or cloth be not efficient, it may be dispensed with; and the glass and filter, being placed on a warm part of the sand-bath, should be covered with a box or vessel large enough to rest on the sand, and thus form a hot-air chamber for the process. When the operations are upon a small scale, a paper cone (1343) is sufficient to cover the vessels on the sand-bath and keep them hot. These filtrations may very often be conducted with great facility by means of a current of hot air directed against the vessels (269).

544. In filtrations of alcohol, or alcoholic solutions, the funnel should be put into the glass, and covered as before

mentioned (541), that evaporation may be prevented as much as possible. In all filtrations for analysis the filter should be covered in the same manner, to prevent accumulation of substances in the upper part of the paper. These covers should in no case touch the filter, but merely rest upon the edges of the funnels.

545. When working upon minute quantities, filters as small as possible are used, that but little of the fluid may be absorbed. When of such size as will result from a piece of paper three inches square or less, they are better not folded, but plain (531, 534), and may then be supported without a funnel upon the mouth of a small test-glass (505). When a lipped Phillips's test-glass is to be used, nothing more is required than to select one having a diameter at the mouth of about one inch and a quarter, or less, according to the size of the filter; from one-half to a third of which, when in its place, is to be left above the edge of the glass. In arranging the filter, the triple or stronger side should be placed opposite the lip, that the form may be retained, and



the space at the lip left open for the passage of air outwards, as the fluid passes into the vessel. These filters should never be filled to a height much above the edge of the glass, otherwise the weight will sometimes bend the paper over the outside, and derange the whole. If the glass used has no lip, then a double fold must be made in the single side of the filter, so as to make a portion from the top to nearly the bottom project inwards and appear like a sharp ridge. When put into the jar, this will form a notch as it were in the side of the filter, by which the air may find a passage outwards. It is necessary in these small filtrations that the air-passage be attended to and kept open; should it be badly formed, or, from the quantity of fluid within, be pressed against the glass, or stopped up by the abundance of liquid which passes through the filter, either filtration will cease, or the fluid, not being able to enter the glass, will flow over and down the outside, and be lost.

546. The dropping-bottles (402) will be very useful in all these filtrations, especially those on a minute scale; and

there is another bottle, recommended by Berzelius, which is also useful. It is formed much like the dropping-bottle, but the cork has no notch in the side, being inserted airtight, and the glass tube has a small aperture. When about half or two-thirds filled with water, it is to be inverted, and then, by applying the mouth to the aperture, air is to be forced in through the tube and water, and condensed as much as possible in the upper part: when the mouth is removed, this compressed air forces out the water in a small stream, which continues for some time, and which, directed against the sides of the filter, washes the precipitate from the paper, and accumulates it at the bottom. It is necessary in many cases to collect the precipitate at the bottom of the filter as much as possible; and for this purpose, besides the dropping-bottle and Berzelius's bottle, a syringe (560) may also be employed. This instrument is easily made from a piece of glass tube at the blow-pipe table (1180), and is very effectual in cleansing the sides of the filter.

547. When a filter is required so large that paper alone has not strength sufficient, a piece of cloth should be fastened by the edges to a slight square frame of wood, so that it may hang loosely; a sheet of filtering paper should be laid over it, and the fluid to be filtered placed upon that. A sheet of filtering paper placed carefully in an earthenware cullender or clean sieve, makes also a large and rapidly acting filter.

548. When the object is hastily to filter a fluid for the purpose of removing pieces of dirt, then a little loose tow at the bottom of the funnel, or a piece of sponge slightly thrust in, is often sufficient for the purpose. Upon some few occasions filters for acids are required. These are generally recommended of powdered glass, being arranged somewhat in the manner described for lixiviation (420). Pieces of glass are put into the neck of the funnel; upon these smaller fragments, then again other layers of particles diminishing in size, until a moderately fine powder has been used, the top being finished by a layer of small fragments, to prevent disturbance by pouring. The pieces

(and initials. In BLOCK capitals)

NAME

Cecile W

DATE

10 NOV 1994

stamped below.

Books will be kept until the date
be reserved.

No books from open shelves may

OF SYPHON.

249

before pulverization, and, should be passed through the matters that may be separated be that of wine-bottles,

ing a fluid from the finely-in, is to allow the latter to former. This is called superior to filtration in d recommended in prefer-lius.

it should be done from a very steady hand, that as ble, before the deposit at l. But a better method by

Let a piece of glass tube, external diameter, 22 inches ent thickness to bear ordi- be bent at the blow pipe shall be about two inches the extremities should be (1166, 1175), until about formed, when filled with t with one aperture closed out at the other, because er diameter of the body of apid passage of fluid than en this instrument is to be ar from the deposit lying

at the bottom, the syphon is to be inverted and inclined, so that the orifice of the shorter leg shall be higher than the other: it is then to be filled with water from the dropping-bottle, taking care that no bubbles of air are included, which is easily done by holding the beak of the bottle against the side of the aperture; and when the water has filled the longer leg, it is to be closed by a finger, and more water added till the other leg also is full. Keeping the finger tight upon the orifice that no air may enter it, the syphon is to be inverted, so as to bring it into its acting position;

the shorter leg is to be introduced into the fluid; and then, by withdrawing the finger, the fluid is to be suffered to run out into a vessel placed to receive it.

551. The current may at any time be diminished, or prevented altogether, by applying the finger partly or closely, against the exterior aperture, and thus complete command in that respect be obtained. As the surface of the fluid descends in the jar and approaches the sediment, care must be taken that the immersed end of the syphon be not brought so near the deposit as to cause any disturbance of it; and towards the last, by diminishing the current and inclining the jar very slowly and steadily, the endeavour should be to remove as much clear fluid as possible, without drawing away any of the precipitate. This may be done, so that not above a cubic inch of clear fluid need be left behind. The syphon is best held in the right hand during the operation, at about the middle of the exterior leg. A degree of government over the current may be obtained by inclining the syphon, so as to bring the aperture of the external leg nearly to a level with the surface of the fluid in the jar, but in all cases it should be kept somewhat below the latter. The jar should be placed in a steady position during the operation, and it is proper to raise it till nearly on a level with the eye. The top of the filtering stand (527, 12) answers very well for these occasions.

552. When a very deeply-coloured solution is to be drawn off, so dark indeed as to hide the end of the syphon when in the middle of the fluid, that end should be brought close to the side of the glass, and a lighted candle held on the outside near it; in this way the precipitate, the depth of the clear part, and the orifice of the syphon, may be seen, when they cannot be observed by any other means.

553. Washing by decantation is much more easily and effectually performed than by filtration, but it requires more water, and hence one great use of a plentiful supply of distilled water (26) in the laboratory. After having drawn off the clear solution, it is merely necessary that the jar be filled up with water, the whole mixed either by a stirrer or by blowing (514), the mixture left to settle, the clear fluid

decanted, and fresh water added; the operation is to be repeated until what is removed contains no soluble matter. Some solid substances contract into a smaller space than others, but even the most bulky should have so much water added to them, as to enable five-sixths to be drawn off after twelve hours' standing. During the time that the deposition is taking place, the glasses or jars should be covered to keep out the dirt. The bottoms of footed glasses (368, 1221) answer this and many other useful purposes; when, therefore, such glasses are broken, the upper part should be chipped away, and the bottoms reserved in a drawer.

554. When the substance has been sufficiently washed, and is left with as little fluid upon it as possible, it may, according to the requisite circumstances of the case, be poured into a basin and evaporated, (as will be described in Section xi. 592, &c.) or poured into a filter to remove more of the fluid, or the water may be removed by means of bibulous paper. There are many bodies, such as chloride of silver, oxide of copper, carbonate of lime, sulphate of baryta, and others, which readily fall in water and occupy but a small space; and which, having been washed, are best freed from the remaining water in the latter method. For this purpose they should be transferred carefully into a small evaporating basin, using the dropping-bottle for washing in the last portions (402, 546), and allowed to settle to the bottom, an effect which is accelerated by moderate warmth; then folding up a piece of filtering paper two or three times, its end should be applied cautiously to the surface and suffered to imbibe part of the water; this done, it must be taken out, the wet end pulled off, and the edge again introduced, as in a process formerly described (69), observing that no solid matter be disturbed during the operation. By taking the precautions formerly given (69); by inclining the basin a little, and by similar attentions, which will suggest themselves at the moment, nearly the whole of the water may in this way be removed without disturbing the substance.

555. The formation of a syphon by a few threads of

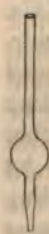
moistened cotton, or by a piece of folded and bent filtering paper, is now and then very convenient for the gradual separation of a fluid. If a basin contain a mixture of fluid and solid matter, and the cotton or the piece of paper be bent over the edge, so that the inner end is in contact with the fluid, and the outer end lower than the inner, the fluid will gradually be abstracted by a syphon action, and the solid matter left nearly dry. A little temporary syphon of this kind is often very useful in refrigerating and other operations; being connected with a vessel of water, it will supply a small quantity of that fluid constantly during a long period of time.

The precautions given to ensure an easy separation of a precipitate (517, 521) must be attended to in washing particular bodies. Prussian blue should always be washed with dilute muriatic acid (519), and sulphate of baryta with weak nitric acid, and if possible with warm water (518).

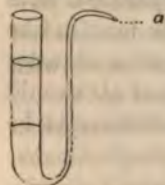
556. It will be observed that the process of lixiviation already described (420) is in reality a washing process. What has been said relative to it will be abundantly sufficient to direct its application to substances generally when necessary.

557. There are numerous cases in chemistry where immiscible fluids are to be separated from each other. Many of these are not difficult, especially where the substances are unimportant or valueless; but sometimes great care is required, because of the value of the bodies, or their dangerous nature. A case of separation by filtration has already been pointed out (542). In other circumstances the two fluids may be poured into a wet funnel (if at least one of the two be water, or an aqueous solution), closed by a good cork beneath, and left to remain on the filtering stand until separated: by partly withdrawing the cork, the lowermost may be almost entirely removed from the upper. Glass vessels, furnished with a stopcock beneath, are made for this purpose. Their use is evident, and requires no description.

558. Another serviceable instrument is a glass tube with

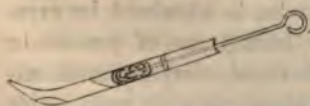


a bulb an inch in diameter blown in it, and drawn out below to a moderately fine aperture (1196, 1179). The aperture being immersed in either the upper or under liquid, the mouth is to be applied above, with the precautions before mentioned (514), and the air withdrawn, when the liquid consequently will enter. The finger being then quickly placed on the upper end of the tube, so as to close it, the instrument may be removed, and the fluid within transferred to any convenient vessel.



559. A useful vessel for the separation of a small quantity of valuable fluid may be made of a piece of glass tube from the third to a quarter of an inch in diameter, by drawing it out in one part until it becomes capillary (1176), and turning it up as in the figure. The point *a* must be closed in the flame of the spirit lamp, the mixed fluids poured into the tube, and suffered to remain till separated. The point *a* is to be broken so as to open an aperture, and then by inclining the instrument, first one fluid, and afterwards the other, may be decanted. The fluids will issue drop by drop into the vessels placed to receive them, and the surface of contact of the two in the fine tube is so small, that scarcely an appreciable portion of the valuable one need be wasted. The pouring, or transference rather, is more steady and regular when the beak *a* is placed against the side of the receiving vessel, so that no drop is formed, but a continuous minute stream.

560. Finally, glass syringes, such as have already been mentioned (546), are very advantageous in the removal and separation of fluids. Such an one as that figured in the woodcut may be used, for instance, in the management of the chloride of nitrogen.* The tow wrapped round the wire which forms the piston, is made sufficiently tight by being moistened with water, and when not inconvenient, a little water



* Brande, Manual of Chemistry.

may be retained both above and below it. The beak of the syringe being brought near the globules of the chloride, and the piston moved upward, the substance enters, and may be collected by holding the instrument in the position in which it is figured. It may then be transferred to other situations, and, if required, be made to issue from the jet perfectly free from moisture. This is effected by holding the syringe, with its beak downward, against a piece of filtering paper, then depressing the piston, till the water, which may be before the chloride, is expelled, and, when the latter is on the point of issuing, by removing the instrument from the damp paper and ejecting the pure substance into the desired place, by a further depression of the piston. Other heavy fluids may in the same way be separated from the liquids in which they lie; and light fluids may in like manner be drawn up and removed, but then excess of water must not be left below the piston, and a bubble of air should be allowed to intervene between it and the substance to be taken into the instrument.

SECTION X.

CRYSTALLIZATION.

561. CRYSTALLIZATION is a very useful and valuable process in the laboratory. It enables us in many cases to purify bodies with great precision; thus by crystallizing the carbonate of soda, a pure salt is obtained, which affords a very available source of pure soda; by crystallizing the acetate and the nitrate, similarly pure sources of the alkali are furnished. Potash, in various states useful for combinations, and free from other alkalies or earths, is obtained by crystallizing the bi-carbonate or the bi-tartrate of potash, or nitre. Pure magnesia is obtained from a crystallized sulphate; pure baryta from a crystallized nitrate; pure oxide of nickel from its sulphate; and pure nitric and muriatic acids are obtained from nitre and common salt, previously

rendered free from other bodies by this process. A second object obtained by crystallization is the very definite and convenient state conferred upon substances by it. A third, the peculiar but precise forms and appearances which it generally imparts to them: these serve as characters, by which known bodies may be recognized, or by which substances before confounded together may be distinguished from each other.

562. Crystallization is always effected in the laboratory by bringing the particles of solid bodies into a mobile state, either by solution, fusion, or vaporization. It is not to be understood that these are the only methods by which crystalline form of structure can be conferred, for there are sufficient proofs to show that a body not crystalline may become so without changing its state of solidity. The crystallization of cooling basalt, as in Mr. Watts' experiments,* or of heated glass, or of barley sugar, or even the spontaneous change of brass wire, which in a few years becomes brittle, are all effects of the latter kind.

563. Considering first the most common case, that of crystallization from an aqueous solution, it is generally performed in one of two ways,—by cooling a hot solution, or by slowly evaporating a cold one. For the due application of the first and most useful method, it is necessary that the substance should be more soluble in hot water than in cold; and the first object is to obtain a hot solution of sufficient strength to deposit crystals when of the ordinary temperature. This may be procured as already directed (378), or a weak solution may be evaporated (592, &c.), till of sufficient strength. A very convenient mode of ascertaining when the solution is strong enough to crystallize is, to transfer a drop of it by a rod (70) to a cold glass plate, and observe whether it deposits crystals as the temperature falls (379).

564. When a proper solution is made, and filtered if necessary, it is to be allowed to cool undisturbed, and the more gradually this is done, the larger will be the deposited crystals. The vessels may be either basins (369), pans, or

* Philosophical Transactions, 1804, p. 282.

such other as may be convenient, having regard to the quantity and quality of the fluid. They should resist chemical action, and generally be of glass or earthenware. They should not be shallow, unless a rapid crop of crystals be required, and then they are to be left open. A depth of fluid about one half or one third of its horizontal width, is the most convenient for the quantities usual in the laboratory. The vessel should be covered over, to prevent evaporation at the surface, where otherwise a crust of crystals would frequently form, disturbing the regularity of the rest. When it is required to cool the whole slowly, it should be covered with a flannel, or cloth, or a cone of paper (1343). Generally speaking, when the solution is strong in the first instance, agitated during cooling, and the temperature diminished rapidly, the crystallization is quick, confused, and irregular, and the crystals small: but when the solution is of moderate strength, the cooling allowed to go on slowly, and the whole retained in a quiescent state, the crystallization is regular, and the crystals are large and distinct. The particular proportions and habitudes of each substance can only be gained by experience.

565. Crystallizations to be effected by spontaneous or very slow evaporation, require a solution saturated at common temperatures. This may be obtained as before mentioned (378), and must have more surface exposed during the process than was required in the former method. Evaporating basins (369) answer this purpose very well. The solution should be put into a dry place, where there is a sufficient access of air to carry off the vapour which will gradually rise from it, and must then be left for a much longer period than in the former case. It is advantageous, if the place be so clean that no dust can fall into the solution to disturb or contaminate it, to leave the vessel uncovered; but if danger be apprehended on that point, it must be covered either with a thin dry cloth, stretched, so as not to incur any risk of its sinking into the solution, or else by filtering paper. When, however, an evaporating solution is thus covered, the process is considerably interfered with, and much more time required.

566. These vessels, as well as glasses, and many others having round apertures, are occasionally very conveniently covered with paper; for which purpose a piece of paper, so large as to overlap the vessel from half an inch to an inch on every side, being placed over the aperture, should be folded down on one side against the vessel. Then a second fold, an inch from the first and partly overlapping it, is to be made; a third upon that, and so on, until the folds have reached round the aperture. These hold each other down, and the last may be fastened by screwing it up tightly, the whole being done somewhat in the manner that a grocer finishes his paper case for a small quantity of sugar. The temporary cover thus formed fits the mouth of the vessel tightly, is strained level over its surface, incurs no risk of sinking into the solution beneath, and being held on by the ledge formed from the succession of folds, is not easily displaced or disturbed.

567. It is by the process of slow evaporation that the largest crystals are obtained. A few of perfect forms should in the first place be selected, and these being placed in the solution, increase in size as the evaporation proceeds, and ultimately become very large. They must be turned every day, that all sides may receive increments of solid matter in succession.

568. An advantageous process between the two now described may often be resorted to: it consists in placing a moderate or weak solution on the sand-bath, in the evening when the fire is going out, heaping the sand round the basin, and leaving the whole until the morning. The evaporation is somewhat hastened, and at the same time the temperature falls very slowly; and thus in many cases a fine crop of crystals may be obtained in a short period.

569. For most substances the first method (563) is preferable; thus acetate of lead, sulphate of soda, nitre, &c., are better so crystallized; but for a few others, the second (565) is most advantageous, and such are common salt, borax, Rochelle salt, sulphate of potash, &c.

570. A very interesting, and in some cases useful process, is the gradual conversion of several small crystals into one

large one. I owe to Dr. Wollaston the description of it. If a small quantity of sulphate of nickel in solution, with a slight excess of acid, be evaporated in a watch-glass, it will probably, on cooling, yield a crop of numerous small crystals; but if set aside for a few weeks in a place subject to the changes of atmospheric temperature, its appearance will gradually alter, the small crystals disappearing, the larger increasing, until ultimately only one or a few large ones are left. This effect depends on the greater extent of surface exposed by the small crystals, as compared to their mass, than by the larger crystals; so that when any increase of solvent power in the surrounding fluid is occasioned by a slight increase of heat in the atmosphere, the small crystals dissolve to a greater extent than the others; but, upon the decrease of temperature, the deposition is equal upon all. In this manner the small ones are gradually dissolved, and the large ones become larger. Thus sometimes a separation from impurities, a perfection of form, or a crystal of magnitude is obtained, which cannot be had by other means. The same effect may often be observed in solutions confined in glass bottles, as in oxalic acid, nitrate of mercury, acetate of lead, &c.; the small crystals which were formed when the solutions were first made being gradually converted into others of considerable magnitude.

571. Other solvents than water must be used for substances not soluble in that fluid, and at times even for some that are. Alcohol is applicable to the crystallization of potash, cholesterine, urea, sugar, &c. Alcoholic solutions are generally crystallized by spontaneous evaporation, unless indeed the solution has been introduced into a retort, for the purpose of distilling part of the spirit, and then the remaining fluid is generally best left in the retort to cool and crystallize. Ether, oil of turpentine, and pyroxylic spirit, are now and then employed in experiments on unknown substances, for the purpose of discovering characters by which they may be distinguished.

572. The influence exerted over one substance by the presence of another, which often materially affects the appearances of crystals and crystallizations, must now be

noticed. Nitre, when crystallizing from solutions containing much common salt, is frequently rough upon its surface, or constituted of a number of crystals, forming a friable, instead of a compact mass. Common salt, when crystallized from a solution containing urea, or in urine, assumes an octohedral form. It has also the same form, though imperfectly, when crystallizing at the surface of a solution during evaporation. The appearances of several salts are altered when crystallized in animal or vegetable infusions. The most remarkable instance of the kind, and one which deserves notice here in consequence of the great apparent difference produced, although not likely often to happen accidentally, is when strong sulphuric acid has acted upon some of the products of distilled or decomposed oil. If one part of the substance obtained by the compression of oil gas, and which always exists as vapour in it, be mixed with eight or ten parts of strong oil of vitriol, a dark liquor is produced; from this, when diluted with water, filtered, and converted by the addition of carbonate of potash into a sulphate of potash, a salt is obtained, which upon crystallization is nacreous, in the form of scales, and has nothing in its appearance common to sulphate of potash. It is, however, that salt, and is thus affected by a substance which sometimes does not amount to a two-hundredth part of the salt present. The same substance has still greater power over the sulphate of copper, and in increased quantities (still comparatively very small) influences the appearances of a great many saline bodies.

573. Sometimes crystallization is *not* effectual for the separation of salts. When the sulphates of iron and copper are in solution together, crystals will be obtained resembling those of sulphate of iron, but with very variable proportions of sulphate of copper in them, the latter salt being present at times in great quantity; on these and other occasions compound salts are formed, as frequently occurs with nickel. But these, and a knowledge of many more extraordinary circumstances attending crystallization, must be left to be obtained by reading and experience.

574. When salts which may be separated from others by

crystallization have been obtained from impure solutions, they always retain a portion of the impurities, and require to be redissolved and recrystallized, before they can be considered as approaching to purity. In particular cases even a third crystallization is necessary.

575. When experiments are proceeding upon an unknown substance or a mixture of substances, to ascertain whether it will crystallize or not, they are generally made as distinctly and effectually upon a small scale as a large one, and often indeed with more success (916). Thin fragments of Florence flasks are useful; as are little dishes, capsules, watch-glasses, and the glass plates already briefly mentioned (1348). Sometimes merely by dipping a rod into the hot solution, and allowing the surface thus wetted to dry in the air, it may be observed from the striated, regular, or uniform appearance, whether the substance has crystallized upon it. At other times, a drop of the cold solution may be put upon a flat glass plate, and the latter placed on a warm part of the table furnace, that the liquor may slowly evaporate, and from the examination of the spot of solid matter left, a judgment may be formed.

576. But perhaps the most decisive evidence is to be gained by leaving a drop or a small portion in a piece of Florence flask to evaporate spontaneously at common temperatures; or, if the substances dissolved are deliquescent, by evaporating them under the air-pump receiver (584). The crusts of solid matter thus produced should be examined with care, as well with a powerful eye-glass as by the naked eye; sometimes by holding the glass plate in the sun's ray whilst it is regarded sideways, or by the light from a candle reflected by it to the eye, or by looking through the crust and glass, not directly at the light, but at a black or white back ground close to it. In all these trials, appearances which resemble crystallization should be closely scrutinized, for the manner in which a film cracks or scales, or the way in which the surface of a fluid in small quantities is drawn by contraction, is often such as to occasion appearances so deceitful as to make it absolutely necessary to refer to an eye-glass.

577. Mr. Daniell has introduced a process of dissection,* which, though not concerned in the production of crystals, is frequently of great advantage in developing them from amorphous masses, and showing the relation of forms one to another. It consists in putting a mass of the substance into a fluid capable of dissolving it, which gradually removing the exterior parts, reveals the interior in their symmetric arrangement. When the substance is moderately soluble, like alum, a lump of it should be put into water, equal to about its own bulk in quantity, and in such a vessel that the fluid may rise a little above its surface, and should be left for several days in a quiet place of uniform temperature. It will then be found, upon examination, that crystalline forms have been developed by the solvent action of the water.

578. Bodies but slightly soluble, as sulphate of potash, may have more water put over them. On the contrary, such as are very soluble, in place of being immersed in water, should be put into a solution of the same substance, which having been saturated, has afterwards been slightly diluted to occasion a solvent action. Substances not soluble in water, but soluble in acids, without effervescence, may be successfully examined in the same manner.

579. As before mentioned, the crystallization of some substances may be effected by fusion, when solution is scarcely applicable, and thus many metals, sulphur, spermaceti, &c., may be made to assume crystalline forms. The process only succeeds well with large quantities, and may be illustrated by reference to lead or bismuth. The metal is to be put into an iron ladle and melted, the ladle removed from the fire and placed on the sand-bath, where, though the bottom may be kept warm, the heat is not such as to prevent the top from congealing. When a solid crust has formed, holes should be broken through it at two opposite parts near the edge, with a hot iron rod, and the fluid metal rapidly poured out. When that which remains in the ladle is examined, it will be found crystallized in the interior. A crucible may be used in place of an iron ladle for metals; a glass flask or an evaporating basin for sulphur, sperma-

* Quarterly Journal of Science, i. 24.

ceti, or similar substances. When the experiment is made with sulphur, the temperature should not be raised too high, or the fluid will thicken and become adhesive.

580. When crystals are to be obtained by vaporization, the general directions given with regard to sublimation (496, &c.) are to be followed; it is to be observed, however, that the more slowly and regularly the crystals are formed, the finer are the forms obtained. It is easy to sublime and crystallize such bodies as camphor, iodine, naphthaline, &c., but with those which demand a higher temperature, as calomel or corrosive sublimate, good crystals can be obtained only by operating with large quantities. The crystallization of indigo is best effected as already described (500).

581. In examining crystals, with a view to recognise their general form and appearance, or the existence of any particular plane, it may be observed that the eye should be assisted by an eye-glass, and sometimes by placing the crystals in the sun's light, or in the light of a lamp or candle, that the reflection from the planes, as they come into particular positions, may render them evident; and it may also be observed, that where small crystals or fragments of substances are to be taken up and examined by the eye, a soft cement, composed of two parts yellow wax and one part turpentine, is very useful (1125). A little piece of this, softened between the fingers, may be fixed on the end of a pencil or a small stick, and formed to a point, or a small roll of the substance itself may be pointed at the end, and the particle being touched by this point immediately adheres to it, and may be examined with perfect ease.

582. With reference to the use of the goniometer, especially the accurate instrument of Dr. Wollaston's invention, and also to the determination of the forms of crystals themselves, these constitute a part of that extensive, important, and mathematical branch of knowledge now known by the name of Crystallography; and for such information as relates to the use of the instruments required in it, the student is referred to the paper by Dr. Wollaston, in the Philosophical Transactions for 1809; and to the different introductory works on mineralogy.

SECTION XI.

EVAPORATION—DESICCATION.

583. EVAPORATION is a process so simple in its nature, and common in its performance, as to be comprehended generally by every one. The ordinary vessels required for it are basins of earthenware (369), one or two of silver and lead (371), a crucible and capsules of platina (371), Florence flasks (373), fragments of flasks (1212), and watch-glasses. The basins and capsules of earthenware should be thin at the bottom, but all these vessels have been sufficiently described in the section upon Solution.

584. Of evaporation, at common temperatures, that which is performed spontaneously has been referred to in treating of crystallization (565), and the necessity of a clean airy place, or of covering the vessels, insisted upon. But the process has been very much assisted and hastened by the use of desiccators, and in the hands of Leslie * was carried to an extent in its power and application, surpassing every previous expectation. Leslie's process consists in placing the fluid to be evaporated in a basin so as to expose considerable surface, under the receiver of an air pump, accompanied by another basin containing a substance which has strong attractive powers for water. Sulphuric acid, having a surface of from twice to thrice that of the fluid to be evaporated, may be used. These should be so placed that the first basin may be supported over the second; and both being covered by a receiver as small as can be conveniently used, it is to be exhausted, and the operation left to itself. The air being absent from within the receiver, a ready liberation of vapour from the water, equivalent in tension to its temperature, takes place; but this vapour is as rapidly condensed upon coming into contact with the sulphuric acid, and in its place supplied by fresh vapour from the water, which in turn is condensed as

* Supplement to Ency. Britannica. Art. Cold.

before. Thus the process goes on, the water travelling in the form of vapour from the basin to the sulphuric acid, where it combines and resumes the liquid state.

585. This process of evaporation, and consequently of desiccation, is valuable, not merely as avoiding any necessity for elevation of temperature, but as actually causing considerable depression, and is for this reason useful in numerous cases where delicate organic substances, which might be injured even by moderate heat, require drying. For its operation, all that is necessary is, to replace the basin of water by the substance to be dried; whether it be fibre, or a filter with a precipitate upon it, or a portion of washed precipitate in a basin, or a solution. All these or any other substances, in basins, may be supported by a little tripod with glass legs, standing in the dish of sulphuric acid.

586. In the general arrangement of this process, it is necessary that the pump be in such order, and the receiver fitted so accurately to the plate, that the vacuum may be retained for days together. It is also necessary that the sulphuric acid be not allowed to become too dilute by frequent use. It is most powerful when first introduced, should be stirred up now and then when the receiver is opened, and had better be replaced by fresh acid when diluted with a fourth or fifth its weight of water. Care should be taken to prevent all contact between the acid and the bodies to be dried; and the student should be aware, that upon the first exhaustion after the introduction of fresh acid, there is generally the evolution of a little air, which, forming bubbles at its surface, break and throw up minute drops. Care should be taken that these drops cannot reach the substance to be dried.

587. Although the arrangement described is the most powerful, it may not always be the most convenient. The substance to be dried may be in a glass or bottle; which may stand in the dish containing the acid, or the acid itself may be in a glass by the side of the substance; but in all cases the acid should be in a very open vessel, for if in a close one, its small surface soon becomes diluted and ren-

dered ineffectual; and moreover, as there is also a tendency in the process to accumulate the portion of air left in the receiver in the vessel containing the acid, it retards the condensation, and consequently the operation.

588. Mr. Cooper has a method of setting several of these operations, on a small scale, at work at one time. It consists in the use of glass plates, in addition to the receiver and its contents. These plates, like those referred to (575, 1348), are of thick plate-glass, but each has a small hole drilled through it at about one-fourth the diameter from the



edge. These plates, with a little pomatum or oil between them, are perfectly air tight, and two thus prepared, being placed together, with the holes coincident, allow a free passage for the air through them, but by being turned a little way round one upon the other, the holes are separated, and the passage closed. Mr. Cooper places a jar with an open ground top upon the plate of the air-pump, on it two of the glass plates with the holes coincident, and the basin of sulphuric acid with its glass and receiver upon the upper plate. The pump is then worked, both receivers are exhausted, and when in that state the plates are moved one upon the other, so as to close the communication, air is let into the lower receiver, and the upper receiver, with its contents standing upon the two plates, is set aside for a few days or a longer time, as may be required. Instead of using the lower receiver, the plates may be put directly upon the air-pump, the aperture in it coinciding with those in the plates.

589. Other substances having strong attraction for water may be used as desiccators instead of sulphuric acid, amongst which are caustic potash, chloride of calcium, quick lime, &c., and Leslie even used well-dried oatmeal, and clay, and with them rapidly froze water.

590. More imperfect, but yet very useful processes, may be practised without the aid of an air-pump. If the acid and the substance to be dried be placed in a proper position upon a glass plate of sufficient size, rubbed with pomatum, and a receiver covering them, accurately closed upon the plate, then, by raising the receiver, introducing the flame

of a spirit lamp for a moment, and suddenly replacing it accurately upon the glass, as is practised by cuppers, an exhaustion will be obtained, imperfect it is true, but which still will usefully facilitate the evaporation.

591. Even without any process of exhaustion, evaporation at common temperatures may be carried on by the use of desiccators, more rapidly in close vessels than in the open air, unless indeed a current be taken advantage of; and a wide-mouthed stoppered bottle, or a jar placed over or in a basin, will at times supply the want of better apparatus. In these cases sulphuric acid, chloride of calcium, carbonate of potash, quick lime, and similar absorbents, may be used. A basin of quick lime, with a moist precipitate placed above it, and the whole covered with a jar or receiver, will soon dry the precipitate.

592. When there is no objection to the application of heat, evaporation may be rapidly effected by its assistance. The heat being supplied in one or other of the numerous methods already referred to in *distillation* (Section vii.), and *solution* (Section vi.).

593. If the evaporation is to be performed at temperatures under ebullition, the vessel used should be an open one, as a basin (369), and have free access of air, that the aqueous vapour may be removed from the surface of the liquid by the aid of the atmosphere, as fast as it is produced (943). When crusts form on the surface, they should be broken down, for they interfere much with the evolution of vapour, acting indeed the same part as a cover, or the film of oil before mentioned (260); the effect which before was advantageous being now injurious.

594. If the evaporation be required to dryness, as is common in cases of analysis, great care is necessary when the solid matter begins to be in such proportion to the liquid as to form a thick mixture. The circulation which took place throughout the fluid mass is now interrupted, and the heat will frequently increase at the bottom of the basin until above the boiling point of the solution, before it can pass by conduction through the crust above it. Then occurs the sudden evolution of small portions of steam,

which cause sputtering and petty explosions, and throw the substance about. In such cases it is necessary to stir the substance continually, that by mixing the whole together the one part may be prevented from rising to too high a temperature, and the other be more readily evaporated to dryness. It assists also in making way for the steam from the lower part, and materially facilitates the desiccation. It is even necessary, when part of the matter has become so dry as to harden into lumps, to use a pestle in place of a glass rod, and by rubbing the lumps down and mixing them with the moist parts, to bring the whole gradually into the state of an uniform dry powder. When this is done for analysis, great care must be taken not to lose any portion of that which adheres to the rod or the pestle: it must be scraped off with the platina spatula, and the rod and pestle being washed with a little water, the liquid must be reserved to be added to the rest in due time.

595. Sometimes when substances which dry hard, as a solution of common salt, are left to evaporate without stirring, they form a cake, between which and the bottom of the basin portions of steam are generated, with a force not merely sufficient to throw out a part of the contents, but actually to cause violent explosions, breaking the basin to pieces, and dispersing the substance in all directions. This is entirely prevented by frequent stirring. When, from the habits of the salt, no fear is entertained of such an occurrence, stirring may be dispensed with in operations not requiring exactness, the evaporating basin being then covered by another to prevent the loss of any small particles thrown up. The upper must then be retained in a heated state, which may be done by filling it with sand, otherwise the desiccation will not proceed, for the vapour condensing upon the cold cover will return to the substance below in drops.

596. If the fluid is to be evaporated at a boiling temperature, there is no necessity for its being done in an open vessel, though it is always most rapidly so performed. It may then be effected either in basins or flasks. In the latter case the dry results are not so easily removed, but that is often of no consequence, and occasionally flasks present

decided advantages. The analysis of a mineral water often requires that large quantities of fluid be evaporated: these being too great for introduction at one time, are introduced by successive portions; and, as much time is required, the evaporation should be performed so as to avoid the dispersion of any part, and prevent the entrance of fumes or other extraneous matter. The quart Florence flasks are then very useful; the boiling, and consequently the evaporation, may proceed rapidly in them on the sand-bath, fresh portions of water being added as that in the flask diminishes, until all is reduced to a small quantity, which may then be decanted, the flask washed out, and this last and concentrated portion treated as the analysis may require.

597. The entrance of dirt at the small aperture of the flask may be prevented by rolling up a piece of paper into a conical form, and putting it loosely into the mouth as a stopper, or covering it in the manner of an extinguisher. Either method will allow free passage for the vapour.

598. When evaporations are going on at the boiling temperature in a basin, it is still more requisite that the vessel be covered, inasmuch as the ebullition will more probably throw small portions of fluid out, and dirt and vapours are more likely to find their way in. The best cover is a second basin put over the first and retained hot (595); or if the evaporating dish be small, one of the bottom covers (553), or a watch-glass may be used. It is necessary in all these evaporations, as Berzelius has observed, that the cover dip in the middle, so that any fluid condensed on it may return to that below, and not run to the outside of the vessel: for the particles of matter in solution being thrown up and caught by the cover, are thus returned to the place from whence they came; whereas in the other case, they would be carried to the outside and lost. The steam makes its way out at the lip of the basin. The necessity during these close evaporations of keeping up the heat, will be evident from the observations already made (425).

599. With a view to particular substances in a mineral water, which it is feared may be confounded with any thing that by possibility could be separated from the glass of a

Florence flask by long boiling, it is sometimes required to carry on the evaporation in a metallic vessel. A deep silver crucible, or vessel, is probably the best apparatus that will present itself, though one of platina would be better. The vessel must be perfectly clean, and covered with a silver or platina dish in the manner just described (598). The water must be added in successive portions.

600. When heat is applied by a sand-bath to a basin during evaporation, the precautions pointed out (381, 382) are to be observed. When the temporary hood (392) is in use, care must be taken that the inside be clean, that nothing may fall from it to contaminate the substance in the basin beneath.

601. Solutions of animal and vegetable substances are frequently to be evaporated and dried, until they become free from water or retain but a small portion of it. In these cases, if the heat be that of a sand-bath or lamp, the temperature is ultimately apt to increase to such a degree at the bottom of the basin, as to cause injury to the substance. The solution, or extract, should be constantly stirred as it thickens, and as a thermometer cannot be applied so as to indicate the heat at the bottom, another method must be adopted for that purpose. Sir Humphry Davy recommended that a chip of wood be retained in contact with the exterior of the basin at the bottom. When the temperature is powerful enough to char the wood, it is sufficient to cause injury to the contents of the vessel, and upon the first indication the latter should be removed. A few slips of paper laid between the basin and the sand, when a sand-bath is used, answer the purpose very well, and indicate by their changes the power of the temperature to which the basin is subject. As some substances decompose by heat before others, it is advantageous to have corresponding indications: and if slips of worn calico or of paper dipped in very weak sulphuric acid be used, they will undergo a change at temperatures much below those which affect ordinary paper. In cases, therefore, where more care is required, the former substances should be used instead of the latter.

602. Similar care is required in the desiccation of organic

substances in a pulverulent or divided state, and they should be continually stirred, if the bottom of the vessel containing them be liable to an injurious elevation of temperature.

603. When substances in powder, not subject to injury from an occasional high temperature, are placed upon the sand-bath to dry, they should be covered with paper (566) to keep out dust. Or if loose covers be more convenient, a glass bottom (553), or another basin, will answer the purpose; but in these cases the cover is to be removed now and then, to allow the escape of vapour, and should be dried before being replaced.

604. In cases of desiccation, it is frequently required to know whether all the water that can be dissipated has risen, or whether vapour be still passing away. A very excellent and delicate mode of determining the point is to cover the dish with a cold glass plate or basin; if dimness appear, it shows that vapour is rising. The test-glass must sometimes remain nearly a minute, or until it is warm, before a conclusion may be drawn, such an interval being necessary to make the presence of vapour visible when in small quantity. Powders supposed to be hygrometric, or to have absorbed moisture from the air, may be heated in a small basin, and tested by this method, and the dryness of extracts, and many other bodies, may be ascertained in a similar manner.

605. Evaporations are frequently performed on a small scale (943), and will occasionally be carried on in capsules or on small plates (1348), or in fragments of Florence flasks; and the spirit lamp (199), the sand-bath (173), and the hot plate of the table-furnace (171), will be in constant requisition as sources of heat.

606. The importance of a current of air in facilitating evaporation, generally, by removing the moist atmosphere and allowing fresh vapour to rise with greater facility, is so well known, that it will be needless to urge its application in every case where it can do no harm and is on other accounts admissible.

607. A warm air-chamber, when it can be obtained, is highly useful for desiccation, evaporation, and similar pur-

poses. It should not consist merely of a cavity or closet, but should admit of a thorough draught of air. One that has been constructed by Mr. Cooper is the best in its principle, and most convenient in its application in the laboratory of research, with which I am acquainted. It consists of an inclosed space placed near the furnace, so as to receive some warmth from it, but rendered fully efficacious in the operations for which it is intended, by a current of hot air traversing it. This air is heated by passing round an iron plate at the back of the furnace, and enters the air-chamber at the top; another passage for its exit commences at the bottom, in a situation as far as possible from the former opening, and is continued until it joins the flue of the furnace at a convenient place. Thus the hot air is made to *descend*, and spread through the chamber by the draught of the flue. A damper is inserted for the convenience of opening or closing the communication at pleasure, and entrance is gained to the chamber by a door which closes accurately and is fastened by a button.

608. A warm air-chamber may be made of brick-work, metal, or even wood, and may be placed in any convenient part near the furnace. An excellent situation for it in the table-furnace (169, 172), exists within the walls and beneath the flue, where the arrangements necessary for heating the current of air will be ready and obvious. Projecting spikes should be fastened into one or two sides of these chambers, to hold a tin plate or a board, to form a temporary shelf when required.

609. Precipitates, filters, and other moist substances put into such a chamber, are readily and safely dried. The hot air causes evaporation of the water, whilst the current removes the rising vapour. The chamber is very useful in effecting the slow evaporation of liquids (565, 568), and also for hot filtrations (543), when the entering current of air is of a temperature sufficient for the purpose.

610. In cases of necessity, a similar chamber may be made by passing the stream of heated gaseous products from a small crucible furnace (269) into one side of a box, and allowing an aperture on the other side, or at the bot-

tom, for its exit: but as dust may pass with the air, it is necessary that the substances to be evaporated or dried be covered with bibulous paper (566). An Argand lamp (270) may be applied in the same manner as the furnace; and in this case even a band-box may be used for the chamber, the hot air entering by a two-inch tube with a funnel termination at one side (1342), and passing out by an opening at the other side, or in the bottom. The chamber should not be too large in proportion to the lamp, but of such dimensions as to be retained at a considerable temperature, and then the water formed during the combustion of the oil will not be deposited; and though it will diminish the drying power of the air, in cases of evaporation, it will still leave it in a very useful state.

611. Where filters with precipitates upon them are to be dried, one useful method is to put them upon a clean tin plate, with a piece of filtering paper intervening or not, according to circumstances, and placing the plate over the sand-bath at a part where its temperature may be sufficiently raised. The sand may be removed from, or arranged over the bottom of the bath at this part, so as to regulate the heat communicated to the tin plate, which should never be such as to char paper; and at other times, when no furnace or sand-bath is in action, the plate may be heated by an oil-lamp placed beneath (212, 270). These arrangements will often be found very useful.

612. Precipitates which have been separated or washed in a filter may have a considerable quantity of the fluid removed from them by being placed upon an absorbent body. A large mass of chalk with a flat surface is exceedingly useful for this purpose, when the fluid to be removed is water; and a sheet or two of filtering paper, folded up into several thicknesses, may be used when the fluid is acid, alkaline, or saline. When the filter with its contents is to be transferred, it should first be loosened at the sides, by inclining the funnel, and then either lifted out by the edges and laid upon the absorbent body, or if too heavy to admit safely of such a method, it should be slipped out of the funnel by inclining the latter, its motion being assisted at

the same time by a slight pull. If the filter be a simple one (531), the side thus laid on the absorbent surface should be that which is single, and then the folds are easily opened, and the filter with its contents laid out. If the chalk be used, it should be separated from the filter by an intervening piece of bibulous paper.

613. After a time proportionate to the nature and quantity of the precipitate, the latter will be found dried to a certain degree. Many precipitates admit of the operation being hastened by folding the filter over them, laying several folds of bibulous paper upon it, and applying pressure with the hand. When the paper has become wetted, dry paper is to replace it, and the operation renewed. This expedient must not be adopted unless the precipitate have so much consistency as to bear the pressure without being forced out at the edge of the filter. After an operation of this kind, the filter with its contents may be removed to the warm air chamber (607), or the hot plate (611), and dried in the usual manner.

614. The solid contents of small filters (545) are frequently dried with advantage in the above manner between folds of paper. It often happens that the substance, though in small quantity, is rare or valuable; in which case the following method may be adopted for the prevention of loss. After being pressed once or twice, it will form a layer within a fold of the filter, the paper being above and beneath, and adhering slightly. Fold one edge of the paper quite back, and then pull it, stripping as it were the paper off the precipitate; this may be done without disturbing the moist cake of solid matter; then double the filter with its contents, making the fold pass through the middle of the precipitate, by which it will also be doubled up, and being pressed a little, will so far adhere that the paper may be bent back and stripped off as before, without disturbing the substance. In this way the cake is reduced to half its original extent, but doubled in thickness, and by repeating the operation, the precipitate, however small in quantity, may be collected from the different parts of the filter into one compact portion.

615. Before quitting the subject of desiccation, it may be remarked that moistened crystals, or other substances in small fragments, are frequently put into funnels to drain, and that the required effect is hastened, and also carried to a greater extent than it otherwise would be, by inserting a folded slip of filtering paper into the neck of the funnel, so that its upper end may touch the bottom of the collection of crystals, and its lower project a little beyond the funnel. Thus situated, it enables the liquor to drain away to a greater extent than would otherwise take place.

616. M. Robinet* has very much improved this process of draining crystals, by passing a current of air through them. If the crystals be put into a funnel with its neck obstructed by a ball of cotton wool, and the funnel be then fixed in one aperture of a double-mouthed bottle, whilst a tube is attached to the other, air may be drawn by the tube through the funnel and its contents into the bottle, and will carry with it the mother-water, or adhering moisture, in such an effectual manner as perfectly to cleanse the most silky crystals.

SECTION XII.

COLOURED TESTS—NEUTRALIZATION.

617. THOSE very important chemical substances, acids and alkalis, in a free state, possess the power, even in very small quantity, of effecting certain general and regular changes in the tints of some vegetable colours. The distinctness of the change, and facility with which it is produced, have occasioned the colours to be used as tests of the presence of these bodies when uncombined or in excess, and are now of such constant service as to be indispensable in the laboratory. They are prepared for use in a state of solution, or fixed upon paper; the preparations being called *test solutions*, or *test papers*.

* Annals of Philosophy, New Series, xii. 460.

618. The only substance of the kind perhaps worth keeping in solution is an acid infusion of red cabbage. For its preparation, one or more red cabbages should be cut into strips, and boiling water poured upon the pieces; a little dilute sulphuric acid is to be added, and the whole well stirred: it is then to be covered and kept hot as long as possible, or, if convenient, should be heated nearly to boiling for an hour or two in a copper or earthen vessel. The quantity of water to be added at first should be sufficient to cover the cabbage, and the sulphuric acid should be in the proportion of about half an ounce of strong oil of vitriol by measure to each good sized plant. This being done, the fluid should be separated and drained off, and as much more hot water poured on as will cover the solid residue, adding a very little sulphuric acid. The whole is to be closed up, and suffered to stand until cold, and then the liquid poured off and added to the former infusion. The cabbage may now be thrown away. The infusion is to be evaporated to one-half or one-third its first bulk, poured into a jar, allowed to settle, and the clear red fluid decanted and preserved in bottles. The residue may have water added to it, the solid part be allowed to subside, the clear liquor drawn off, evaporated, and added to the former, or it may be dismissed altogether. This solution will keep for a year. When required for use, the acid of a small portion of it should be neutralized by caustic potash or soda (not by ammonia), when it will assume an intensely deep blue colour, and will, in most cases, require dilution with twelve or fourteen parts of water. The red liquor of pickled cabbage will occasionally answer the uses of the solution, and is, when required for service, to be neutralized in a similar manner.

619. Test papers are far more advantageous for use than liquids: two of them in general application and delicacy surpass the rest; these are litmus and turmeric papers. For the preparation of the former, some good litmus is to be rubbed to powder with hot water in a mortar, the mixture poured into an evaporating basin or a flask, and water added until the proportion is about half-a-pint for each ounce of litmus. It is to be covered up so as to remain

warm for an hour, after which the clear liquor is to be decanted, and fresh hot water poured on to the residue. This is to be covered up as before, suffered to stand, and the liquid evaporated. The operation is to be repeated a second time, and if much colour appears to be removed, even a third. The first solution is to be kept apart from the second and third, which may be mixed. The first portion will not require evaporation, but the others are to be so far reduced in quantity, that when a piece of filtering paper is dipped into them, and dried, they will impart to it a blue colour of sufficient intensity for use.

620. Paper is then to be dipped into the prepared solution. The paper should in all cases be bibulous, and not sized (529), so that fluid dropped upon it should be instantly absorbed. Sized paper often presents a fairer tint of colour upon the surface, but is by no means so delicate as a test. The paper should be of a good colour, that the tint may not be injured; of sufficient thickness not to become almost transparent when wet; and particular care should be taken that it be free from earthy matter, especially carbonate of lime, and alkalis. It may be examined as to these points in the manner recommended for filtering paper (529).

621. The paper selected should be cut into pieces of a size convenient to be dipped, somewhat less, for instance, than half a sheet of post paper. The litmus solution should be poured into a dish or soup-plate, and the paper should be drawn through it piece by piece, in such a manner that the fluid may be in contact with both sides, and then having been held to drain a few seconds, it should be hung on lines of thread or twine to dry, in a convenient place. No fumes of acid or burning charcoal should have access to it, for they injure the colour; and as soon as the paper is dry it should be taken down, and laid together. The tint ought to be a full blue, or if light, not faint or undecided: it may be judged of by touching a piece of the paper with a very weak acid, and observing whether the red colour produced is vivid, and in strong contrast to the blue tint of the rest of the paper. If the solution should have been made so dilute as to produce too weak a tint, the paper may be dipped a

second time; but this is to be avoided if possible, as it involves a second exposure to the air.

622. It may happen from the suspension of fine particles of litmus in the solution, that the tint is not so clear as was required, but has a dusky appearance. This is unpleasant, but is not injurious; the fine particles of litmus testing the presence of an acid nearly as well as the stained paper.

623. When the paper has acquired its proper colour and is dry, it should immediately be tied up closely in stiff paper, and preserved from the air and light: the latter injures and destroys its colour, and the former, from the carbonic acid and other occasional substances it contains, injures the colour, and consequently the sensibility of the paper.

624. Turmeric paper is to be prepared in a similar manner. A hot infusion of finely-bruised or coarsely-ground turmeric is to be made, by boiling one ounce of the root with ten or twelve ounces of water for half an hour, straining through a cloth, and leaving the fluid to settle for a minute or two. The liquid should be of such strength that paper, when dipped into it and dried, should acquire a fine yellow colour. The paper should be of the kind before described (620). No particular care is required during drying, relative to exposure to air, except that acid and alkaline fumes should not have access, as they may transfer injurious matter to the paper, and diminish its delicacy. When dry it should be wrapped up and preserved with care.

625. The stock of test papers should not be left lying about the laboratory for general use, for then much is torn up carelessly and wasted, and much more spoiled by floating fumes. But a piece of each should be cut into slips about six inches in length, and half an inch in width, and either put into a stoppered bottle, with dark paper pasted round it to prevent the entrance of light, or, what is more convenient, tied up in a case of cartridge paper, the slips projecting about half an inch at each end, that one, either of litmus or of turmeric, may be withdrawn at pleasure.

626. In using these test papers with a fluid suspected to contain free acid or alkali; or, knowing that one of these

substances is predominant, to ascertain which is so, all that is necessary is to moisten them with the liquid, and observe the change: if the fluid be acid, the blue colour of the litmus will immediately become red; if alkaline, the yellow colour of the turmeric will be changed to a brown. The moistening may be effected by dipping the paper into the liquid, but a better method is to touch the edge of the slip with a rod dipped in the fluid (374). In the latter case there is no risk of contamination to the fluid from the paper, and only a very minute quantity of the liquid is used at once.

627. These trials must be made by day-light; artificial light not permitting that just estimation of the changes by which the presence of a small excess of acid or alkali is to be determined. As the proportion of free acid or alkali diminishes, the intensity of the new tint produced upon the paper is also diminished, and when in very small quantity it requires considerable attention before a decision can be arrived at. The test paper should occasionally be touched with pure water in the immediate neighbourhood of the part where the solution has been applied; for any change in appearance that may have occurred, not due to mere moistening, is then readily perceived.

628. Although acid is generally tested for by litmus paper, and alkali by turmeric paper, yet the former is sometimes used advantageously for the latter purpose, being first slightly reddened either by exposure to the air, or by momentary contact with muriatic acid fumes. When the paper thus modified is used instead of turmeric paper, to detect a free alkali, that substance is indicated by the restoration of the original blue colour. Litmus paper is best slightly reddened for this use, by putting a drop or two of muriatic acid into a large jar, allowing it to stand a few minutes, and then bringing the paper towards the mouth of the jar, or carefully placing it within; so soon as the blue tint has become slightly reddened, the paper should be removed for use. If too much acid be imparted to the paper, the delicacy of its indications is injured, because of the greater quantity of alkali required to neutralize the

acid, and restore the blue colour. For the same reason a paper free from alkali or carbonate of lime has been recommended for the preparation of these tests (620), for these impurities combining with a minute portion of acid, neutralize it, and thus prevent that delicacy of indication which the test paper ought and may be made to possess.

629. Litmus contains a portion of alkali, and so also does litmus paper, in consequence of which it becomes insensible to liquids very weakly acid, when applied in the small quantities above directed, because the acid present in the drop is neutralized by the alkali of the paper, and therefore has no effect on the colour: but in these cases there can be very little free acid, and if absolute certainty as to its existence, or not, be required, it is then better to cut some little squares of the test paper, the one-tenth or one-twentieth of an inch in size, to put one of these into the liquid, and move it from place to place. If there be the smallest trace of free acid present, the alkali of the paper is quickly neutralized, and then the blue colour changed to red.

630. Neutralizations are best effected with the assistance of heat, especially if a carbonate be used, or if precipitation occur during the operation. The carbonic acid in the first case is dissipated, and in the latter the combination is more rapidly and perfectly effected. Evaporating basins (369) are highly useful for these purposes, their contents being easily stirred, and the rod used for that purpose also applied to moisten the test paper when required. The solution to be neutralized should not be very strong, and the substance added should be diluted (511) upon approaching the point of neutralization, if it be accurately required, for the reasons before given. The successive trials on the test paper should be made down own edge, and occasionally contrasted with the effect produced by water (627). On very delicate occasions this comparative trial should be made with hot water, heated in a small basin by the side of the larger one containing the solution. Great care should be taken that the paper be not brought into contact with acid fumes during the trial; or much error may inadvertently be occasioned.

631. Sometimes precipitations are to be effected in neutral solutions, by the addition of an alkali or an alkaline carbonate, it being desirable to have as little excess of the latter as possible. Turmeric paper is then required, and the operation should be performed by heat as before mentioned; but instead of adding the precipitant gradually to the whole of the solution, until slight indications of an alkali in excess appear, it is better to reserve a small portion of the solution, and then rapidly rendering the rest slightly alkaline, afterwards to add the small portion by degrees, testing with the turmeric paper until the point is as nearly attained as required. The small remaining part may then be precipitated, by adding alkali carefully and continuing to test it, and finally joining it to the larger portion.

632. There are many substances which affect the colour of test papers, and especially of turmeric paper, either independently of the free acid or alkali they contain, or with appearances different to those described; which, if unknown, might sometimes lead to error. Solution of boracic acid, whether strong or weak, gradually changes turmeric paper, producing a tint resembling that occasioned by an alkali; and, if previously mixed with the common acids, produces still stronger tints of red and reddish-brown. The borates occasion the same effect, especially when mixed with acids, and some of the tints very much resemble those produced by alkalies. Strong oil of vitriol, and muriatic acid gas, redden turmeric paper, but the redness is removed by the addition of water. Ammoniacal gas, on the contrary, does not redden turmeric paper, unless there be sufficient water present in the paper to dissolve the gas. The salts of iron, tin, and uranium, the muriates of zirconia, zinc, antimony, and manganese, and the nitrate of bismuth, when in moderately strong solution, produce tints in turmeric paper, resembling those occasioned by excess of alkali. It should be remarked, for the instruction of those who, meeting with a difficulty of this kind, may resort to paper stained yellow by rhubarb, that it also is affected in the same way, though not so generally, but that, with particular care, it is a very excellent test of the presence of alkalies.

633. *Alkalimetry* frequently consists in an estimative process, dependant upon neutralization and the use of the test papers just described; the object being to ascertain the quantity of free alkali or of carbonate contained in any impure specimen, as for instance, in that produced by the first rough process for their preparation. Descroisilles first resorted to neutralizing power for this purpose, but the extent to which the application has been improved by chemists since his time may be seen in modern works.

634. Let a tube, closed at one end, of about three-fourths of an inch internal diameter, and nine inches and a half in length, have 1000 grains of water weighed into it; then let the space it occupies be graduated into 100 equal parts, by the processes formerly described (129, &c.), and every ten divisions numbered from above downwards. At 23.44 parts, or 76.56 parts from the bottom, make an extra line a little on one side, or even on the opposite side to the graduation, and write at it with the scratching diamond (128) *soda*; lower down, at 48.96 parts, make another line, and write *potash*; still lower, at 54.63 parts, a third line marked *carb. soda*; and at 65 parts a fourth, marked *carb. potash*. It will be observed that portions are measured off, beneath these marks, in the inverse order of the equivalent numbers of these substances, and consequently directly proportionate to the quantities of any particular acid, which will neutralize equal weights of the alkalies or their carbonates. As these points are of great importance, it will be proper to verify them by weighing into the tube first 350, then 453.7, then 510.4, and lastly 765.6 grains of water, which will correspond with the marks if they are correct. The tube is now completed, except that it should be observed whether the aperture can be perfectly and securely covered by the thumb of the left hand, and if not, or if there be reason to think it not ultimately secure, then it should be heated and contracted until sufficiently small. (Sect. xix.)

635. Diluted sulphuric acid must now be prepared to be used with the tube. When of a specific gravity of 1.1268, it will be very nearly, if not accurately, of the strength required; and this may be obtained by mixing one part by

weight of oil of vitriol of specific gravity 1.82, with four parts of water. If, when cold, the specific gravity of this diluted acid be as above mentioned 1.1268, it must be nearly, if not exactly, of the strength required; but before being admitted into use, should be examined experimentally. Assuming it, however, as being absolutely correct, it will be found that a quantity measured into the tube up to any one of the four marks described, is sufficient to neutralize 100 grains of the dry alkali or carbonate set down at the mark; consequently, if water be added in the tube thus filled up to any one of the marks, until the 100 parts are full, and the whole uniformly mixed, one part of such diluted acid will neutralize one grain of the alkali or carbonate named at the mark, up to which the tube was first filled with the acid of specific gravity 1.1268.

636. When a specimen of potash, barilla, or kelp, is to be examined by this instrument, 100 grains are to be weighed out, dissolved in warm water, filtered, the insoluble portion washed, and the solution added to the rest; by this process the alkali will be separated from carbonate of lime, or other insoluble matters, which otherwise might cause errors in the estimation. The alkaline solution is to be put into a basin on the sand-bath, and then the tube and acid prepared. For this purpose some of the acid, of specific gravity 1.1268, is to be poured into the tube until it rises up to the mark indicating the substance to be tested for; potash or carbonate of potash for the potash or pearlash of commerce, and soda or carbonate of soda for barilla or kelp: then water is to be added carefully (402), until the hundred parts are filled, and closing the tube with the finger, its contents are to be perfectly agitated and mixed.

637. The alkali in the basin is now to be neutralized with the acid in the tube. After having once placed the thumb of the left hand over the aperture of the tube, it is not to be again removed; but inverting the tube by turning the hand so that the thumb and the mouth of the tube are downwards, the acid is to be let out gradually into the alkaline solution, by relaxing the thumb and admitting a succession of small bubbles of air; the hot solution beneath is to be

continually stirred, so as to mix the acid instantly with the whole, and the operator must proceed with increased caution as the point of neutralization is approached. Very small quantities of the acid may be added, by slightly relaxing the thumb so as to permit a minute quantity, less than a drop, to flow to its extremity, and touching it with the glass rod; the final adjustment may thus be made more accurately than by dropping the acid from the lip of the tube. The process must be carried on until the alkali is found by the test papers to have been exactly neutralized (627, 629): then the tube must be inverted, the thumb removed, drawing its under surface over the edge of the tube, so as to leave as much as possible of the fluid that otherwise might adhere to it, and having allowed the sides to drain, it must be observed how many parts of acid have been used, the number of which will indicate the number of grains of the alkali or carbonate, contained in the 100 grains of the impure alkali operated with.

638. With respect to the proper strength of the acid (635), it is to be examined in the following manner: crystals of bicarbonate of potash are to be fused in a platina crucible, the fluid poured out upon a clean, cold metal plate, and a piece of the resulting solid, estimated to be 70, 80, or 100 grains, weighed in water (72); in this way a known weight of pure carbonate of potash will be obtained in solution. The solution is then to be diluted, heated, and neutralized by acid from the tube diluted as before described (635), from the mark of carbonate of potash. If it be found that as many parts of the acid have been used as of grains of the carbonate weighed out, the acid is of proper strength: if more acid has been used, it is too weak; if less has been sufficient, it is too strong. Suppose, for instance, that 100 grains of the salt (fused carbonate of potash) had been used, and that 90 parts of the acid were sufficient; then these 90 parts ought to have occupied the 100, and consequently the 100 parts contain one-tenth too much acid, in consequence of the experimental acid itself containing one-tenth more than it ought to do. Hence the latter must be diluted with such a quantity of water as will make nine

volumes into ten, or by one-ninth its volume; for as the 90 parts used are to the 100 parts they ought to have occupied, so is any number of parts by volume of the acid under trial, to the number of parts which it ought to occupy. The difference between the two last numbers will give the quantity of water in volumes, to be added to the acid expressed by the first of them, in order to correct it and make it of proper strength. On the contrary, if it were found that the 100 parts were insufficient, and that 10 parts more of similar acid were required, then there is too much water by one-eleventh of the whole in bulk, the correction for which would be one-tenth more of the 35 parts of acid put into the tube up to the mark 65 carb. potassa. This tenth is 3.5 parts, but as only a fifth of that or 0.7 parts is acid, therefore 0.7 parts by weight of the same oil of vitriol that was used before must be added for every 35 parts of the mixed acid. The correction in any other case may be easily made, by considering that the number of parts over a hundred which are necessary to saturate the 100 grains of carbonate of potash, are proportionate to the quantity of oil of vitriol which must be added to bring the experimental acid to proper strength: thus if 136 parts of the diluted acid were used, then thirty-six-hundredths more of the weight of oil of vitriol already used must be added; and the quantity of oil of vitriol that was added at first being known to be one-fifth by weight (635), the additional quantity required is easily ascertained. These corrections are not strictly accurate, but sufficiently so to meet even the exaggerated cases put of a difference of 10 parts, and to bring it within the limit of errors of experiment.

639. Sometimes instead of using test papers, a little of the neutralized blue cabbage liquor (618), or of infusion of litmus may be put into the alkaline solution; the former immediately assumes a green tint: and by attending to the change effected by the addition of the acid, and noticing the point when blueness is again restored to the cabbage-colour, or when the litmus becomes reddened, the indication of neutrality is sufficiently evident and accurate for general purposes. The test by papers is, however, more precise.

640. Some of the impure sources of potash and soda used in the arts, contain, amongst other substances, sulphuret and sulphite of alkali. Both these occasion errors in the mode of estimation above described, to obviate which MM. Welter and Gay Lussac* advise, that after the soluble parts have been separated by water, a little chlorate of potash should be added to them, the whole evaporated and heated to redness. This converts the sulphuret and sulphite into neutral sulphate, and then upon redissolving the whole, the caustic and carbonated alkali may be ascertained as before described.

641. A process of neutralization, quite the same in principle, may be adopted for the purpose of estimating the strength of *acids*, but from circumstances it is not often used, and being easily comprehended from the above directions, claims no further notice here. Acetic acid is at present the substance which most frequently requires some such estimation as the above, both because its specific gravity varies very little with its strength, and because it is much in use in the arts in an impure state. Dr. Paris has pointed out the near agreement between the equivalents of acetic acid and carbonate of lime, and has proposed to estimate the strength of this acid, by allowing it to act upon a known weight of fragments of carbonate of lime, and ascertaining the quantity dissolved, which will at once express the quantity of pure acid present. Vinegar, however, or impure acetic acid, is not very readily neutralized by pieces of carbonate of lime.

642. In the same manner muriatic, nitric, and any other acid, which forms a neutral soluble salt with lime, and has had its equivalent number well ascertained, may be estimated, and its strength become known. Thus let 500 grains of the acid be put into a basin or flask with 100 grains of marble in fragments, and after the first effervescence is over, warmed, and the neutrality ascertained; the solution is then to be poured off, and the remaining pieces of marble washed, dried, and weighed. The number of grains of carbonate of lime dissolved in muriatic acid multiplied by 0.74, indicate

* *Annales de Chimie*, xiii. 212.

the number of grains of dry acid by which it has been dissolved ; and the number dissolved in nitric acid multiplied by 1.08, also represent the equivalent of dry nitric acid, or the quantity present in the solution submitted to experiment.

SECTION XIII.

CRUCIBLE OPERATIONS—FUSION—REDUCTION.

643. OPEN vessels, intended to receive bodies to be subjected to high temperatures, have received the name of crucibles. They are very various in form and material, both for the sake of economy and to fit them for peculiar uses. By far the greater number are formed of earthenware ; they are cheap, they resist a high temperature, and also the action of most bodies which, from their fixedness, admit of or require the application of heat. They must, however, be distinguished from each other.

644. Ordinary *English crucibles* are easily scratched by a knife or glass, and break with a granular crumbling fracture. They are useful for many common purposes, may be had of a triangular or circular form, with covers of the same material, and are cheaper than any others. Some of them, called subliming pots, have well-fitted, dome-shaped covers, and are exceedingly useful for many common operations. They will bear a bright red heat, but will not resist a very high temperature ; for in it they soften and froth, and frequently occasion the loss of their contents. In consequence of their approach to fusibility when hot, fluxes render them quite fusible, for which reason they will not retain these agents long. The latter find rapid entrance and access to the interior in consequence of the porosity and softness of the vessels, which, of course, allows easy penetration by the fluid : after being heated for a short time with a coloured flux, and then cooled and broken, the extent to which these agents penetrate them may be readily observed.

645. *Hessian crucibles* very far surpass the common English vessels in resistance of high temperatures and the action of fluxes. When powerfully heated even to softening, they do not become vesicular. They are triangular; they are not accompanied with covers, a want very often felt in the laboratory. They are usually of a brown colour, are harder than English crucibles, scarcely yielding to a knife or to glass; they are more compact, and are interspersed with black particles; the fracture is sharper. The price is about 7*d.* for the nest of five or six crucibles.

646. *Cornish crucibles.* Round and triangular crucibles of different sizes are made in Cornwall for the use of the assay masters, and are now plentiful in London. They are equally good with the Hessian crucibles. They resist a very high temperature, and on softening do not become vesicular and frothy. They agree with the Hessian crucibles in hardness, fracture, and in all points except colour, being white or nearly so; covers of the same material may be obtained.

647. When crucibles of fine ware are required to retain fused substances, as certain fluxes, glasses, &c., by far the best for the purpose are those made of Berlin porcelain. They do not crack easily with change of temperature, they resist a very high heat, and retain fluid bodies well. They are also supplied with covers. They may be obtained with the other varieties of crucible at Knight's, in Foster-lane, and elsewhere in London.

648. *Blue pots or black-lead crucibles* are made of a mixture of coarse plumbago and clay, and are generally of large size, being intended principally for use in the arts. They bear a higher temperature than the English crucible, are not so liable to crack when suddenly heated or cooled, and resist the action of fluxes better than most others at moderate furnace temperatures; but as they contain abundance both of iron and charcoal, they cannot be used in experiments where either the one or the other would be injurious. Covers to these crucibles of the same material may be obtained.

649. Of all these varieties the Hessian and Cornish cru-

cibles are the most valuable in the laboratory. They are generally used singly, and uncoated, but on particular occasions it is advantageous to place one in another, and by taking two successive ones from a nest, a double crucible may thus be obtained, which is not very clumsy. They may either be placed simply one in the other and then used, or compacted together thus:—Stourbridge clay (1101), mixed with water into a smooth and rather soft paste, should be put at the bottom and about the inside of the larger, in such quantity that, on introducing the smaller, and applying pressure, it may come in contact with the clay in every part, the excess being thrust out at the edge between the two vessels. It requires some power to force in the smaller crucible and displace the excess of clay. This object is best effected by placing the crucibles with the mouths downward on a table, and pressing on the bottom of the larger, whilst a little twisting or lateral motion is given, until its edge is also in contact, or nearly so, with the table. The two crucibles being thus by the intervening clay compacted into one, must be put into a warm place (607), and left for some days to dry. They must not be used in a damp state.

650. Charcoal crucibles are very convenient for certain operations of reduction. Klaproth recommended that they be formed by making a cavity in a piece of well-burned charcoal, answering to the size of the substance to be operated with, with a charcoal stopper to close the mouth. The charcoal vessel is then to be fitted into a common clay crucible, which last is to be well covered and luted.

651. Stoppers or covers may be made out of solid charcoal, and as that of alder wood does not crack or fly to pieces when heated, it is best adapted for the purpose; but it is requisite previously to heat the charcoal to a high degree, in consequence of the contraction which that substance undergoes, and which appears to be proportionate to the temperature it is submitted to. Charcoal made as it usually is, by mere ignition, when fitted and then subjected to high heat, will be considerably deranged, from the contraction occasioned by a greater temperature; but if previously strongly ignited, this derangement is avoided.

652. For purposes of reduction it is often advantageous to line crucibles with charcoal. The charcoal should be pulverized, and the more compact and close the lining is required, the finer should be the powder; for in consequence of the porosity of charcoal, its powder lies in a much smaller space than the solid or coarsely pounded substance. It is to be mixed with weak gum water, not putting so much as to make it adhere, but forming with it a moist powder; the crucible is to be lined with a coat of this, from the fourth to the half of an inch or more in thickness. The cavity is to be finished by a smooth mould, or rather core, as the end of a pestle or a properly formed piece of wood; and having pressed the lining as hard as possible with this, it is to be withdrawn carefully, first giving a little rotatory or lateral motion, so as to set it free from the lining without causing derangement. The crucible is then to be set in a warm place to dry (607).

653. Amongst metallic crucibles, those formed of platina are most generally useful: they should be accompanied by covers of the same metal. They are usually made with a flat bottom meeting the sides at a sharp angle, and then have the advantage of standing steadily; but they are peculiarly liable to injury at this angle, not only because they are often thinner there than elsewhere, but from blows upon the outside, and from endeavours by means of hard instruments to loosen their contents. The substance adhering to it should, on account of the value of a platina crucible, be loosened as much as possible by solution, and afterwards removed by smooth or blunt bodies, as glass rods, or spatulas. By making the crucible with a round bottom, or egg-shaped, the disadvantages attending the angle are avoided, but the inconvenience of not standing by itself is incurred. It is, however, when hot, easily supported in the sand-bath, and when cold, either there or on the top of a test glass (505). The two forms are equally well supported in the furnace.

654. Platina capsules have been before referred to (371). They are useful in heating bodies either in the furnace or by the spirit lamp, and often supply the place of crucibles.

When a cover is wanted, one will serve that purpose to another, or even to the platina crucible itself; and the crucible cover may be useful in conjunction with the capsules.

655. A platina crucible may often be inserted with advantage into a Cornish one, but it is better not to introduce any intervening substance. The metal crucible is thus protected from impurities in the fuel, and from the forcible action of the tongs in moving it into and out of the furnace.

656. A silver crucible and cover is a useful vessel; it may in many cases be used instead of the platina crucible, and being of a cheaper metal, may be formed of larger size. It is of great service in the evaporation of mineral waters, and various solutions. It should be of pure silver. It should be carefully attended to when heated, because silver fuses at a full red, or rather yellow heat; and because in a furnace, amongst the fuel, there are frequent air-ways and currents of small extent, by which one part of a crucible is rendered much hotter than another. It should be understood, that as the heat approaches the fusing point, there are certain temperatures at which the crucible will appear quite whole and sound, even when it is so friable and brittle that if held at one edge its weight is sufficient to break a piece out. Hence it is best never to trust it in any other than the crucible furnace (158), where it can be most conveniently watched, and where the heat is not so liable to rise unobserved as in a close furnace. It may sometimes be put with advantage into a Cornish or other earthen crucible.

657. Klaproth, who has the merit of first applying fixed alkalies to the analysis of minerals by heat, found silver and platina crucibles so much acted upon by them, as to be induced to make, and earnestly to recommend, a vessel of pure gold for this purpose. Such a crucible is by no means liable to the same kind or extent of injury as the former, but is very fusible in the fire.

658. No other furnace fuel than charcoal should ever be used to metallic crucibles. The sulphurous fumes which rise from coke and coal injure them; and iron and other substances present do not merely form slags, which adhere to

the vessels and soil them, but actually corrode and destroy them.

659. These crucibles gradually deteriorate and become injured by successive operations; platina frequently rises into blisters which are exceedingly inconvenient, not merely as weakening the vessel, but as forming cavities; portions of the matter fused in the crucible are retained in these cavities, and being very difficult of removal, often remain and cause injury in future operations. The surface of the metal, also, gradually becomes roughened, and the whole is rendered more or less brittle. The purest platina undergoes these changes in time, partly perhaps from the fumes of the fuel in the furnaces, or the slight, but successive action of the substances heated in it. Silver crucibles change much more rapidly, and after some time acquire a crystalline structure and become very brittle.

660. An iron crucible is occasionally required; though but seldom for experiments of ignition. On the whole, though a more fusible material, it is better of cast than of wrought metal.

661. When, in the absence of crucibles, an extemporary vessel of this kind is required, it may either be a tobacco-pipe, or a piece of green glass tube luted, or a china cup or its fragments.

662. In the appropriation of metallic crucibles to particular uses, it is to be observed that fusible metals, or compounds of metals likely to be reduced, must never be heated in vessels of silver, gold, or platina; otherwise alloys will be formed, the crucible destroyed, and its contents lost. Even several chlorides which are unchanged in and cause no injury to glass, will, when heated in platina under ordinary circumstances, injure it. This is the case with chloride of lead, which being partially reduced, the crucible becomes lined with an alloy of lead, and seriously injured. It is the same with oxide of lead and many compounds containing that metal, such as flint glass. These crucibles should be used, therefore, only with infusible substances in mass or powder, or with such fluids as will not act upon them. In analyses the chemist is frequently obliged to

heat alkalies in them, because no other vessels resist their action so well. Caustic alkalies act at a high temperature upon both platina and silver, though not rapidly: the action is much increased by free access of air, and seems to be dependant in part upon the formation of a portion of the peroxide of the alkaline metal, oxygen being afterwards transferred from it to the crucible. The carbonated alkalies do not act upon either, but they cannot be fused safely in silver, from the high temperature they require. When charcoal is mixed with the carbonated alkalies, action takes place slowly on platina, perhaps in consequence of the formation of a portion of potassium.

663. When the characters exhibited by earthy bodies, upon being heated, are to be ascertained, the earths must not, as Klaproth has shewn, be put into earthen crucibles.* Vitrification frequently takes place, in consequence of an action which occurs at the surface of contact, when it would not happen in crucibles of charcoal or metal.

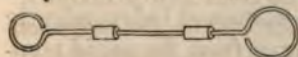
664. Earthen crucibles are best adapted for the retention of metals at high temperatures, and consequently for all experimental attempts to reduce them; but there are certain liabilities to which they are subject, of which the student must be aware. The action of fluxes upon them has been already noticed (644), and it is such that they will not stand in the fire beyond a certain time, proportionate to the temperature and dissolving power of the flux. They also occasionally yield substances to the bodies heated in them; thus platina heated highly with charcoal in an earthen crucible, will be found to have combined with silicon, if at least the temperature has been carried up to the fusing point; and either wrought or cast iron, in like manner heated intensely in an earthen crucible, will be found to have acquired silicon, and perhaps aluminum.

665. Finally, with reference to the selection of these vessels, it is generally best to reject an earthen crucible that has once been used, except it be large, in good condition, and required for a repetition of a former process. For the numerous small and varied experiments made in the labo-

* Klaproth's *Analytical Essays*, vol. ii. pp. 35, 36.

ratory, it is always advisable to commence with clean vessels, and to throw them away when done with, lest any impurity should be communicated to an important result. The cheapness of crucibles removes the charge of extravagance from such a practice; one failure in an experiment is of more consequence than the second use of several earthen crucibles.

656. The apparatus for the application of heat requisite for crucible operations, as lamps, furnaces, &c., have been already described (Sect. iv.); so that now there remains but to notice such circumstances as peculiarly relate to their use with crucibles. The small and the large spirit lamps (199, 205, 228) answer well for platina crucibles and capsules, when the heat they communicate is sufficient; for no fumes arise which can occasion injury to the metal. If the tranquil flame of the lamp be hardly sufficient, the broken flame obtained by the blow-pipe before described (233, 245) may be used. The crucible may be conveniently supported



by a piece of iron-wire, bent so as to form a ring at each end, one about two-thirds of an inch and the other one and a quarter inch in diameter, separated by a straight line seven inches in length; the wire should be pushed, before being bent, through a couple of phial corks, which, when brought to the middle of the straight part, serve as a handle, and prevent the hot metal from burning the hand.



667. The heating power of the tranquil flame is much economised, and the temperature of the crucible increased, by using a jacket like that represented partly in section and partly in perspective in the wood cut. It is to be made of sheet copper or iron, open at the top and bottom, and within it, three projecting slips of iron plate are to be fixed by rivets, intended to support the crucible on their edges. This jacket is to be sustained on the ring of a retort stand, the crucible placed within it, and the spirit lamp beneath. The supporting slips should be of such dimen-

sions as to leave a space of nearly half an inch between the crucible and the jacket, in which the flame moving tranquilly, wraps itself around the crucible, and as no flickering motion takes place, every portion is thus effectually applied. The loss of heat from the crucible by radiation and contact of cold air is very much diminished, and this is still further lessened when the cover is on the crucible. A very important difference in the temperature of the contents of a metallic crucible, depends upon the circumstance of the cover being on or off. The spirit lamp used to heat the crucible must bear some proportion to the size of the vessel, and the quantity of its contents. The two mentioned (199, 205) are sufficient for most purposes when platina crucibles are used.

668. The jacket is also of highly advantageous application in the use of an oil (212, 213) or gas lamp (215), and is often economical in distillations, evaporations, &c. A second, on a larger scale, must then be used for the larger sized retorts, and it should not have supporting slips within, but the jacket and retort should be sustained independently of each other; for otherwise the edges, from the rapid manner in which they become heated, would often occasion the fracture of the glass.

669. In considering the relations of furnaces to the crucibles that may be heated in them, it is hardly necessary to notice the table-furnace (169). Any crucible less than six inches in height, and four inches in diameter at the top, may be heated to full redness in it. It may be set on the fuel, and raised now and then when needful by tongs, or be put upon a square piece of soft brick about an inch thick, placed upon the bars. As before mentioned, coke should be the fuel used (192), and a cover (of common English ware or black lead) should be applied, when the highest heat is required; the furnace-door should be shut, the ash-door open, plenty of fuel around and upon the crucible, and all extra flues communicating with the chimney closed.

670. When a crucible is to be heated in a crucible furnace (158), the grate should be placed in it not less than half way from the top (160). The furnace should be of such a size as to allow at least two inches of space for fuel

all round the crucible, when the latter is two inches in diameter or less, and somewhat more if it be so much as three inches in diameter; this will permit the supply of fuel in sufficient quantity to produce a strong heat. When a fire is to be lighted in the furnace, a few pieces of charcoal may be put into a common fire, and when ignited placed in the crucible furnace, and being afterwards covered by charcoal, the combustion will soon become sufficiently vivid. If the crucible to be heated be of platina, it may be placed on the fuel, the cover put on, and charcoal added to the sides. Unless a strong heat be required, it will not be necessary to place fuel over the crucible; but if there be occasion for a high temperature, the fuel is to be piled up, and even the flue (165) used. As the fuel sinks, it must be re-adjusted with the tongs, the crucible raised, and, if the heat has not been continued long enough, fresh fuel is to be added. The crucible should never be allowed to sink to the grate. If it contains a soft or pasty substance, it should be carefully watched, to prevent its position from being deranged, or the cover displaced. It will acquire the highest temperature when about an inch and a quarter from the grate, equally distant from the sides of the furnace, covered with about an inch of fuel, and with the temporary flue over it.

671. If the heat is to be continued longer than during the combustion of one charge of fuel, a stand should be used for the crucible. Stands of common earthenware are sold with crucibles; or the stand may be a small crucible about one inch and a half high, turned upside down, with a little sand or refractory clay between it and the experimental crucible; or an English cylindrical crucible with the mouth upwards, either empty or filled with sand; or a small round pillar of soft brick (1354). It should be put into its place, the furnace lighted, the crucible arranged, the fuel added, and the heat raised. The fuel should not be suffered to burn down very low, nor should much be added at once; but the addition should be gradual and continual, that the crucible may never be left exposed to the air, if the experiment has in the first instance required it to be covered. Cold fuel sud-

denly diminishes the temperature of that part of the fire with which it comes in contact, which if it occur where the crucible itself is situated, causes injurious variations in its temperature.

672. The temperature of a furnace should never be allowed to rise and fall suddenly and irregularly, whilst an operation is going on. Such changes are liable to affect the temperature of the crucible, and even to cause its fracture.

673. The utmost heat that can be given to a crucible is to be attained in the laboratory by such a blast-furnace as has been already described (184); the fuel being coke, or coke and charcoal (187, 191, 193). When of the dimensions specified, it will heat a crucible three inches and a half high, and two inches and three-quarters in its upper diameter, very highly; and one not more than one inch and three-quarters diameter at the top, intensely. To acquire the most powerful heat, the crucible should be raised about one and a half or two inches from the grate, and covered with at least the same depth of fuel. Hence arises a necessity for supports and covers, capable of resisting intense temperatures. The best supports would be crucibles made of the Cornish or Hessian clay, of a cylindrical form, from one and a half to two inches in height, and from half an inch to an inch internal diameter; the closed end being put upon the grate, and the bottom of the crucible on or into the aperture above, where it would be steadily retained. But in the absence of such supports, recourse must be had to Cornish or Hessian crucibles, and one being selected with a flat bottom, it must be placed upside down, with the mouth upon the grate. From the irregular form of the bottoms of these crucibles, and the necessity of choosing them as narrow as possible, that the fuel may be close to all parts of the crucible to be heated, the latter is necessarily, when simply placed upon the stand, very tottering; it is, therefore, generally advisable to lute the crucible and stand together with a little Stourbridge clay, a small portion being put between the two surfaces, and more at the side, so as in fact to make the

two vessels into one, their bases being attached together. Such luting must be well dried for a day or two before it is placed in the furnace (1084).

674. With respect to covers, the arrangement is more difficult, in consequence of the absence of those necessary accompaniments to Hessian crucibles, and the uncertainty attending the supply of them with Cornish crucibles. Suppose that iron or steel is to be heated without contact of carbonaceous or extraneous substances of any kind. A common English cover will not answer the purpose, because it will melt and run into the crucible. A larger crucible of the same kind may be turned over it, and luted at the edges; but this inconveniently increases the size of the mass to be heated, which, when the highest temperature is required, should be as small as possible. A smaller crucible of the same kind may be inverted and put *inside* the other, and the interval filled by a luting of Stourbridge clay; but the heat contracts the lute, the fissures of which may receive particles of fuel and slag. This is the more probable, because in all cases of a blast in the surface from below upwards, there is an eddy in the stream of air above the crucible, which stands as a fixed obstacle in the current, and which causes the return and accumulation of numerous small particles upon the top.

675. The method that has been found to answer best, is to beat up some Stourbridge clay with water into a stiff paste, to make it into a cake the fourth of an inch thick, to put it over the top of the crucible, to press it down with a common English cover of proper size, so as to force a cake of the damp clay into the crucible, and cut off the excess by its edge, and then to finish by luting the edge of the cover and the side of the crucible together. This is to be done before the crucible is luted upon its stand, and the whole is to be well dried previous to being used. When heat is applied, the internal cover of lute becomes baked, and though it diminishes in size, yet, from the form of the crucible, it seldom sinks down to the charge; and if the English external cover soften and fuse, it is still supported on the former, and generally serves to keep out impurities.

676. When the crucible is of charcoal, or is lined with charcoal, and consequently has a charcoal stopper inside (651), the common cover may be put directly over it and luted; and even in plain crucibles, when charcoal is not injurious, an internal cover of it, formed out of one or several pieces, may be used instead of the plate of lute, and the ordinary cover then put over it.

677. The furnace being clean and in order, and the crucible with its luted cover and stand dry, the latter is to be placed steadily on the grate of the furnace; a few pieces of lighted charcoal are to be dropped in and covered by cold charcoal to the depth of two or three inches, and the whole left until the combustion has spread amongst the fuel; the air will find sufficient access through the aperture beneath. When the crucible becomes warm, coke is to be added so as to cover it, and the temporary flue (165) is to be adjusted, to assist the draught. When the fuel is nearly red hot an inch or two below the surface, more coke is to be added until it rises about two or three inches above the crucible, the flue is then to be replaced, and the combustion to proceed until the crucible itself is red hot. This will occupy perhaps an hour, and require attention only at the short intervals when coke is to be added. The course described is adapted to the object of raising the heat steadily and gradually to redness; it may be well to explain, that the coke should not be put on until the crucible has been somewhat warmed by the charcoal, to prevent the deposition upon it of the water driven from the fuel. Having attained a red heat, the flue must be removed, the bellows applied (185, 188), slowly at first, and more powerfully as the heat rises, until the highest point required, or that is possible, be attained.

678. It is very desirable that the heat should be raised regularly, and sustained steadily. For this reason the blast should not be variable, but uniform. As the combustion goes on the fuel will generally fall freely, but it should be touched now and then by the tongs or an iron rod, in order that, if hollow places should occur, they may be filled up without delay. The fuel should never be allowed to burn

away very low, and then a large quantity of cold fuel piled on; but it should be supplied at small intervals, the top of the crucible never being left uncovered, except purposely, to observe that it has not melted down. Cold fuel should not be allowed to come in contact with it; even bright red hot fuel will cool a white hot crucible. All these precautions in heating the crucible are necessary to insure the fullest advantage that may be attained in the short time which an operation in this furnace generally requires. When the crucible is large, or double, or is lined with charcoal, or contains a considerable charge, it is some time before it acquires a temperature approaching to that of the fuel on the outside; and if the heat has been raised in an intermitting manner, or if the fuel, after being allowed to burn low, has been replenished by cold portions, the furnace may have appeared very hot occasionally, and yet no proportionate effect be obtained within the crucible.

679. When very high temperatures are required, as in the fusion of platina or rhodium, the crucibles become so soft as to sink and fold like leather, and the results are often lost. This is sometimes due in part to the pressure of the fuel upon the crucible, and may be prevented by hanging a shelter over it. A long narrow English pot, having a mouth a little larger than the crucible to be heated, is to be selected, and a hole made through its bottom; by passing an iron rod with a hooked end through this hole, the pot may be suspended in an inverted position over the crucible and within half an inch of it, thus preventing the contact of the fuel with its top. Care will be requisite that the expansion of the rod and vessel, as the heat rises, should not cause the latter to press upon the crucible. A great depth of fuel is, on these occasions to be preserved in the furnace round the shelter, to compensate as much as possible for its effect in diminishing the temperature; and this, with a little more than common application of the bellows, is always sufficient for the purpose. In this way many crucibles and their contents have been saved, which, from the average of experiments without the shelter, there is reason to believe would have been lost.

680. When an operation in this furnace is considered as concluded, it is best to withdraw the bellows, and to let the temperature sink a little before the crucible is disturbed, otherwise the heat will be unbearable, and the vessel from its softness will be liable to injury. If allowed to cool entirely in the furnace no harm results, and occasionally much advantage.

681. Whether this or any other furnace be used, care is necessary in moving the crucibles with the tongs when in the fire, or in putting them in and taking them out. If heavily laden, and nipped by the tongs at one edge, they should not be held too upright, lest the weight break them. Attention should also be paid that no impurity be communicated to their contents, from the tongs or from the fuel, by awkward management. If the charge is fluid, as in analytical processes, the tongs should never touch any part of the inner surface where the fused matter has adhered, lest they not only convey impurity, but remove a part of the charge.

682. The following general remarks upon the objects of these operations may be useful. If the object be the ignition of a mixture for analysis, or the desiccation of analytical products, then a platina crucible with its cover, raised either by the lamp or the charcoal furnace to a moderate red heat, is sufficient. When the substance is to be weighed, or the loss of weight ascertained, the crucible is first to be counterpoised, then weighed with the substance in it, afterwards heated and weighed again to ascertain if there be loss. The remaining substance is then to be removed, and the crucible weighed for the last time, to see that the counterpoise continues correct. Or if it be a substance to be dried, as silicia, it is first to be weighed, then heated carefully and weighed with the crucible after it has been heated; the substance is then to be removed, the crucible wiped, and the diminution of weight ascertained. In that way the quantity of dry matter it contained may be estimated better than by transferring the substance itself to the pan and weighing it, or if the latter be done, the weight may be verified by the former method: for it is easier to remove and clean *all* the substance out of the crucible, than

to put it *all* into the balance pan. If a substance to be fused or dried decrepitate by heat, it should first be pulverized (315), or in less precise cases the crucible should be covered. If the object be to observe the changes that may take place in bodies by heat, attention must be paid to the precaution pointed out by Klaproth (663) and others, as to the mutual action of the crucible and the substance.

683. When the end to be obtained is the mutual action of bodies, then the crucible, being charged, is to be heated gradually, fluxes being used as seldom as possible; for although they are very advantageous in cleansing the reduced metal, and assisting its separation from embarrassing impurities, they corrode and weaken the crucible, as before mentioned (644). In making alloys, the metals are to be well agitated together; for in some cases, even when apparently miscible and well mixed, there is, as Mr. Hatchett and others have shewn, a remarkable tendency to separation.* In the preparation of alloys, and the fusion of some metals, it is advantageous to cover the surface of the metal with pieces of charcoal, to prevent oxidation. In these cases a loose cover should be put on after the charcoal, to hinder the access of air, and prevent combustion as much as possible.

684. When, in an analytical process, potash is to be used, which alkali may be added as carbonate, then the bicarbonate is very serviceable, for it will fuse down without ebullition, an effect which always take place if the carbonate is used, or even pure potash, and is often injurious.

685. *Fluxes* are very frequently required in cases of chemical action amongst metallic compounds at high temperatures, and often cannot be dispensed with. Their use is to protect the substance from the air; to dissolve impurities which would otherwise be infusible; and to convey active agents, as charcoal and reducing matter, into contact with substance operated upon.

686. *White flux* is made by deflagrating a mixture of equal parts of nitre and cream of tartar in a large earthen crucible, heated red hot at the bottom. The mixture should

* Philosophical Transactions, 1803.

be introduced in successive small quantities, the combustion of one portion being allowed to arrive nearly to a termination before another is thrown in, or the substance will be blown out of the crucible. That part of the flux which has been in contact with the sides of the crucible, when removed from it, should be separated from the rest, and preserved apart; a little earthy matter being usually derived from the vessel, which, though ordinarily of no importance, may be of consequence in delicate experiments. The flux should be retained in a closed jar or bottle. It consists almost entirely of carbonate of potash, the nitric acid of the nitre and the combustible tartaric acid of the tartar having both been destroyed; indeed the process has for its object the preparation of a carbonate of potash from the two salts used. This flux disintegrates ordinary earthy or stony matter, dissolves silica, separates acid and sulphur from metals, assists in the oxygenation of many metals, and dissolves many metallic oxides. When charcoal is present it decomposes portions of the flux and yields potassium, which sometimes combines with the metals beneath. Antimony, bismuth, and some other metallic bodies thus become highly alloyed with potassium.*

687. *Black flux* is made from a mixture of one part nitre and two parts crude tartar, deflagrated as before in a crucible, hot enough to cause feeble combustion; the result should not be raised to so high a temperature as to cause fusion. From the quantity of tartar used, this flux contains an excess of charcoal resulting from the tartaric acid; hence it differs from the white flux, with which it would otherwise agree, in containing a reducing agent. The charcoal frequently assists in converting metallic oxides into metals by abstracting the oxygen. The flux yields potassium in the manner before mentioned.

688. *Crude tartar, argol, or cream of tartar*, when decomposed by heat, yield a carbonaceous carbonate of potash. It is used sometimes with advantage as a flux, from the accuracy with which it may be mixed with the pulverized substance whilst in the state of tartar. The intimate man-

* Serullas: *Journal de Physique*, xci. 123, 170; xciii. 115.

ner in which the charcoal and potash of this flux are mixed, causes the evolution of much potassium. The action of these carbonaceous potash fluxes is influenced by the potassium evolved, the reductions frequently depending to a considerable extent upon it.

689. *Nitre* is a salt frequently added to the contents of a crucible for the purpose of communicating oxygen to some of the metals, and converting them into oxides. Potash is left, which operates as a solvent of the oxides produced, and acts, generally, as the fluxes already described. If the substances present be such as easily combine with oxygen, the nitre should be added carefully and gradually, lest a violent and sudden action be occasioned.

690. *Sal Enixum* is an acid sulphate of potash formed in the manufacture of nitric acid. It is powerfully corrosive and cleansing in the crucible, and acts at first as an acid from the excess which it contains. This excess is soon either neutralized or driven off, and, when charcoal is present, often occasions the production of a sulphuret, which, being injurious in certain experiments, is then to be avoided.

691. *Borax* being a more expensive salt than the former, is a flux more rarely used, and only for the cleansing or melting of the most valuable metals, such as gold, rhodium, &c. It is a ready solvent of metallic oxides generally, and yet does not act so rapidly upon earthenware crucibles as potash, or alkaline fluxes containing carbonate of potash. It has little or no action on silver, gold, or platina crucibles.

692. All these fluxes act upon earthen crucibles, some more than others. They are not used with metallic crucibles except to dissolve adhering impurity, and to cleanse them.

693. *Common flint glass* is a very good flux in many cases, and exerts but little action on earthen crucibles. But it contains much oxide of lead, which is reduced if any charcoal or combustible substance be present, and even by the access of smoke. Many metals, as iron, zinc, &c., and several ores, also reduce portions of the lead, and thus the buttons of these metals beneath such a flux become contaminated.

694. *Green bottle glass* is a very serviceable flux at high temperatures, but when charcoal is present, it yields iron; even traces of silicium and alumium have been observed in iron previously pure, after being heated with it.

695. These fluxes are sometimes pulverized and mixed with the ores or other substances to be acted upon, before being introduced into the crucible, and sometimes are gradually thrown into the crucible afterwards. The method to be adopted must depend upon the different circumstances of the substance to be operated with, the flux, and their mutual action. It is necessary that care be taken upon first introducing the crucible into the fire that the heat and action be moderate, lest from the ebullition which always takes place in consequence of the liberation of either gas or moisture, a part of the flux should flow out, and thus a portion, even of the valuable part of the contents, be lost. As the ebullition diminishes, more of the mixture (if any remain) may be added, and when all is in, and the charge is less agitated, the heat may be raised until the metal be fused; or if an action is going on, until the flux itself become quiet and tranquil; a result which generally indicates the cessation of chemical action.

696. In consequence of the very common occurrence of metals in the state of oxide, their deoxygenation is most frequently the object of a crucible operation, and carbon in one form or another is the agent generally resorted to. It is for this reason that tartar and black flux are so valuable as fluxes. Charcoal is frequently added to the oxide to be reduced, in quantity greater than that contained in the flux; sometimes indeed no flux at all is used, it being actually injurious from its affinity for oxides, and from being in opposition to those affinities which assist in reducing the metal. A charcoal crucible, or a crucible lined with charcoal, is useful for the reduction of some oxides, as that of iron for instance,* and also for the deoxygenation of sulphates and their conversion into sulphurets; but in other instances, when the oxides are infusible, and yet cannot be thus reduced by cementation as it were, the charcoal may be pulverized and mixed with the oxide, and the mixture

* Berthier. *Annales de Chimie*, xxvii. 24.

introduced into the crucible. In these cases it is generally best to use a crucible lined with a thin coat of charcoal.

697. There are several substances which occasionally surpass charcoal as reducing agents; sometimes because they mix more intimately with the oxide in powder, and at others because they either are fluid, or melt when heated; and being absorbed, are present everywhere in the mass, and when decomposed leave charcoal wherever they have had access; but they should be such bodies as bear a high heat without being dissipated, or when decomposed leave much carbon. Of this kind are starch, gum, sugar, wax, spermaceti, oil, fat, tar, and pitch.

SECTION XIV.

FURNACE TUBE OPERATIONS.

698. THE operations to be described in this chapter are such as require a high temperature, like those just referred to, but being performed with substances in either the gaseous or vaporous state, or for other reasons, require another description of apparatus for their confinement and subjection to the necessary heat. The vessel now to be adopted is a tube, and by its means either gases or vapours may be subjected alone to great heat, or they may be passed over solid or fluid bodies previously raised to a high temperature. On both these accounts the methods about to be described are very common and useful.

699. Different tubes are required for different occasions. They are frequently made of earthenware; these resist a high heat, except that they are liable to crack in the fire; but this fault may in part be guarded against by previously luting them, for the reasons and in the manner directed with respect to earthen retorts (492, 1084). In addition to the directions there given for luting, it may be observed, that, with respect to tubes, the lute, after being put on as

stiff and as tightly as possible, may be surrounded by a long slip of sampler or open canvas, running round it in a spiral manner, so that each fold may overlap the last (1094 : this will retain the lute in its place during desiccation, and prevent the occurrence of cracks. The porosity of ordinary earthenware has been before mentioned (489, 492), and if necessary must be guarded against as much as possible by washing the tube with borax, &c., as already directed (492). But when the loss of a part of the gas is of little importance, as when it is passed into a tube to operate upon the substance within without reference to quantity, then the porosity of the tube does not much interfere.

700. Tubes of the Berlin earthenware (369) are most excellent : they bear a very high temperature ; they do not readily crack in the fire ; they are impervious to vapours, and are very little acted upon by ordinary vaporous substances. Wedgwood's tubes are of pure ware, but very liable to crack. Tubes of the same material as that used in the manufacture of common English crucibles are not so subject to this failure, but are more porous. Black lead tubes, or such as are made of a mixture of clay and plumbago, are least liable to crack of any, but sometimes communicate iron, and are very porous. These tubes are frequently bent into the form of a narrow U, when they may be readily introduced into the mouth of a common furnace, the two ends and apertures being outwards, and close together. When straight it is advantageous to guard them in the furnace by a semi-cylinder of tin-plate, and at times they are conveniently strengthened by being passed through a cylinder of plate-iron, roughly turned into a form which may serve as a casing.

701. *Iron tubes* are constantly useful. A gun-barrel, when convenient as to size, answers the purpose very well. When larger or smaller tubes are necessary they must be forged for the occasion. If required for a long operation, or at a temperature above a red heat, they should be protected from the fire either by luting (699), or by being passed through a black lead tube. Iron tubes are generally adapted for the decomposition of organic substances,

as oils, &c., or water, or potash by charcoal or iron, or of gases that have little or no action upon the metal, as ammonia and carburetted hydrogen.

702. A *platina tube* can scarcely be dispensed with in the laboratory of research, because of the very high temperature it will bear, and the few instances in which it interferes with the substance passed through it: substances may be heated together in it which cannot be so treated in any other kind of vessel. Chlorine, sulphur, and the metals, are almost the only bodies which affect it; oxygen and acid gases have no power of action on it. Those are best which are drawn, and have no joint down the side, but they are the most expensive. Those which are turned or bent, and soldered with gold, will not bear the high temperature of the former, and it is impossible to make a joint without solder, which will continue tight. The platina tube may often be used with advantage as a retort, by the adaptation of a plug to one end, which may be removed or replaced at pleasure.

703. *Glass tubes* are the most generally useful of all. They allow operations performed in them to be watched up to a red and even a yellow heat, and some kinds of glass resist the action of most chemical agents likely to be brought into contact with them in this form. The best tubes are those made of Bohemian potash glass, and used by Liebig in his analyses of organic bodies: they bear a sudden heat without cracking, and a high heat without softening; they contain no lead, and are not easily acted upon by ordinary agents or vapours. They are hard and strong, of a very good colour, and may now be purchased in this country at Knight's, Foster-lane, and elsewhere. After them come the tubes of green bottle or crown glass; they require care in heating, but resist the action both of heat and chemical agents much better than those of flint glass. The latter include in their composition both alkali and oxide of lead, substances which are liable to be acted upon in many experiments. They soften also, and are easily expanded, and collapse at a red heat, but to compensate in part for these bad qualities, they may be readily obtained any where

in England, whereas the others are scarce. When of small size they are readily bent into the required form, by a spirit lamp and mouth blow-pipe. Glass tubes may, like those of earthenware, be strengthened by luting, but it is generally so desirable to witness the action going on within, that a semi-cylinder of tin plate, or of earthenware, will be found a more advantageous support.

704. The method of connecting these tubes, when in the furnace, with parts of other apparatus by which the gas or vapour is either to be introduced or conveyed away, must vary with the substance of the tubes. They should be of such length as to leave the ends projecting sufficiently far from the furnace, to be either of moderate temperature, or to allow of the application of cooling processes; which, however, should only be applied to metallic tubes, and then with caution. When the tubes are metallic, terminating pieces with ground joints or screws may be brazed or welded on, and thus junctions are easily effected; and in these cases if the ends be hot, washers of card should be applied at the screw (830), and not such as are made of oiled leather; for the latter gradually decompose and become unsound. It is often of use in operations with the gun-barrel, to terminate it at each end by a stop-cock, of which the outer extremity has been formed into a ground socket; perforated wooden or cork plugs, formed at one end so as to fit tightly into these sockets, and at the other into a screw, may then be used as adapters; while they complete the junction, they prevent the transmission of heat.

705. If the tube be of earthenware or glass, and the extremity be cool, the junction may be effected by fitting on a cap (832), or by a perforated cork, or by caoutchouc connectors (449), or by any of the processes already described, or to be described in the *sections* on gaseous manipulation, and on lutes and cements. If the terminations be hot, the object must be attained by applying some of the methods described in the latter *section*.

706. When vapours are to be passed through a heated tube, it will be necessary to generate them in a little boiler or a retort, connected with one end of the tube. In such a

case the joint must be capable of bearing the heat requisite for the existence of the vapour, and the neck of the retort and the associated part of the tube should be wrapped up in flannel or paper (473), that loss of heat, and consequent condensation of the vapour there, may be prevented as much as possible.

707. The adaptation of furnaces to the heating of these tubes for general operations will be readily understood. When crucible furnaces are used, the tube should be placed in two notches (158) cut in opposite sides, so as to bring the upper part of the tube below the level of the edges, and the grate should be raised to within one inch and a half of the tube itself. If one furnace be scarcely wide enough to heat a sufficient length of tube, a second may be arranged by its sides, the tube passing through the notches and lying over both. It is easy, by piling the charcoal over the edges of the furnaces where they touch, to heat the tube there; and a brick or tile, or other body, should be put on each side, bearing against the two furnaces, for the purpose of interfering with, and as far as may be, preventing the current of air, which will otherwise pass towards the junction of the two crucibles, and in ascending tend to cool the tube at that part.

708. By placing two bricks edgewise, across a loose square grate, four, five, or six inches distant from each other, a space is left between them, which makes an excellent tube-furnace; it may, by the use of several bricks, be arranged to heat any desired length of tube. Charcoal is to be the fuel used. But, when a much higher heat is necessary, and even the application of a blast required, it is better to build up a temporary furnace with bricks and mortar, setting the tube in its proper position in the course of the work; and as the brickwork is not required, nor is likely to be, of much durability, it will be safe, before putting a fire in, to tie it round with iron wire. When the heat is to be raised to a high degree, it will be proper to introduce a stay or two, pieces of black lead tube, for instance, as supporters to the lute.

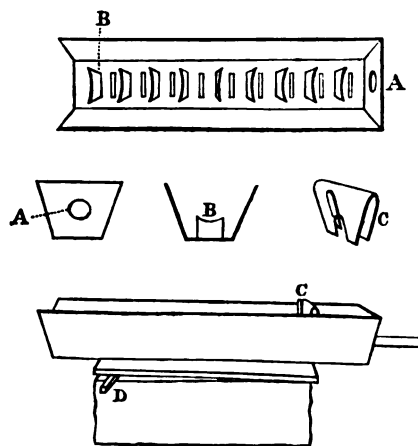
709. A small piece of glass tube may be heated in a

spirit lamp, and a greater portion in the oil lamp (212). The tube may either go through holes in the sides of the chimney, just above the top of the flame, or it may be bent thus  so as to pass down the chimney, until the lowest part of the tube is just above the flame. The concentric double-wick oil lamp (213), or the large spirit lamp (205, 206), answers for these purposes very well.

710. The ignition of a tube has now become an essential part of the process of organic analysis. For this purpose Dr. Prout and others used spirit lamps, having a row of wicks placed in a line, at such a distance from each other as to heat the tube with considerable uniformity, and also to a sufficiently high degree. The rapid advance of this branch of chemistry in the hands of Prout, Berzelius, Dumas, Liebig, and others, have made the tube-furnace and the heating of a tube matters of the first importance. It is no part of my duty to treat of these in detail: as regards the different departments of chemical science, it is only the first principles of manipulation which belong at present to us. Accordingly I shall describe Liebig's furnace, because

it is valuable in the heating of many tubes, as well as for the particular service of organic analyses, and refer him who wishes to pursue the practice of this branch of chemistry to Liebig's own work, containing every necessary precaution.*

711. The furnace is a box of sheet iron, open at the top and at one end; 24 inches long, 3 inches high, 3 inches wide at the bottom, and 4½ inches



* Instructions for the Chemical Analysis of Organic Bodies, by Liebig; translated by Dr. Gregory. Griffin, Glasgow; Tegg, London. 2s. 6d.

wide at the top. At the closed end is a hole A, through which any tube to be heated may pass. The lower edge of the hole may be about $1\frac{1}{2}$ inches from the bottom of the furnace. Eight or nine supports, B, of plate iron are fixed to the bottom of the furnace at equal intervals, and are of such height ($1\frac{1}{2}$ inches) and shape as to correspond with the hole A, in their use of sustaining the tube. Apertures are made in the bottom of the box between each support, and perform the office of a grate to the furnace.

712. Charcoal is used with this furnace. It is made red hot in an ordinary fire or furnace, and then applied here. To retain it in its place, and to allow of the extension or shifting of the fire as any operation proceeds, screens of strong sheet iron are employed of the shape delineated, C, the notch allows them to pass over the tube to be heated, and their form fits them to and holds them steady in the furnace. The screens are to be moved as the fire is to be extended or contracted.

713. The usual position of the furnace is upon a tile or paving stone, being so placed that all the apertures in the bottom, except upon occasions the first and second, are closed by the tile D. If a slight degree of inclination in the direction of the length of the furnace is desirable, for the purpose of preventing any fluid that may have been formed or sublimed from returning towards the heated part, it is easily given by inserting an iron wedge, D, under one end of the tile. If, when the furnace is in operation, it be required to raise the heat to a higher degree, the furnace is raised a little at one side, and sustained by the introduction of two thin pieces of tile at different places. This allows air to enter by the apertures forming the grate of the furnace, and so increases the intensity of the combustion. A still higher heat may be gained by fanning the upper part of the fire with a sheet of pasteboard.

714. When glass tubes are subjected to high temperatures in any of these furnaces, it is often advisable, for many reasons, to inclose them in a tube of copper foil (1351); this supports the glass when so hot as to become soft, confines and prevents it from being expanded into

bulbs by the pressure of gas within, and assists in conducting the heat uniformly over the tube. It also conveys heat to those parts of the tube not yet subjected to the flame, and by gradually warming, prepares them for its application; so that no sudden change of temperature is ever occasioned, and tubes of common glass are consequently more safely heated. This external case is made of a slip of copper foil, about an inch or an inch and a half wide, and so thick that twenty-five or thirty folds squeezed by pincers may be equal to about the tenth of an inch. The foil, after being flattened, should be rolled up tightly into a small cylinder, bound with a piece of wire, and heated to dull redness for a moment, to destroy the degree of rigidity given to it by pressure between the rollers. Being then cooled and opened out, it is to be wrapped close round the part of the tube to be heated in a spiral, one fold overlapping another at the edge. When so much of the tube is enveloped as is required, the extra length of foil is to be torn off, and the end kept tight upon the tube by a turn or two of thin wire. The casing should also be confined in one or two other places by a turn or two of wire. The case thus formed is more or less thick, and consequently strong, in proportion to the degree in which the turns are folded over each other. If a fold overlap the previous one by one half, then the case will be of double thickness; if it overlap two-thirds, of triple thickness; if it overlap but a little at the edges, the case will consist of little more than a single thickness of foil.

715. Glass tubes, whether guarded in this way or not, generally require support in the middle to prevent them from bending. This support is provided in Liebig's furnace. In other cases it is given by a moveable stand, made of thick iron wire fixed perpendicularly into an iron bottom, and terminating above in a loop or ring, or sometimes in a crutch. Such stands support short pieces of tube closed at one end, and are also useful in the arrangement of other tubes as well as those which are straight.

716. When gases or vapours are to be passed through tubes at high temperatures, for the purpose of effecting

their decomposition, it will be advantageous to increase the surface of contact, and also to break the uniformity of current within. Broken rock crystal, or flint, answers this purpose very well with glass or earthenware tubes. The crystal or flint should be divided in a mortar into coarse particles, if the tube be large, or if much deposited matter be expected from the decomposition; or into smaller, if the tube be small, or if but a slight action, accompanied with little deposit, be anticipated. A crumpled piece of wire should be thrust into the tube near to one end, a few large pieces of the broken substance dropped in at the other to rest upon the wire, and, afterwards, that which is considered of a proper size is to be poured in. If two or three larger pieces, and then more wire be added, they will retain the charge in its place; but the wire should be such as will not injure the experiment, for which reason also it is better to place it generally out of the heated part. Platina wire answers the purpose for small glass tubes, and will rarely occasion harm.

717. Some substances have singular powers in influencing the decomposition and even combination of gaseous bodies and vapours, although they have no apparent tendency to combine ultimately with either the compounds or their elements; and it is for this reason that tubes of different substances operate differently upon the gases passed through them. If ammoniacal gas be passed into a red hot iron tube, it will be easily decomposed into nitrogen and hydrogen gases; but if it be passed through a glass tube, as Gay Lussac has shown, it resists an equal and even a much higher temperature, with scarcely any change. This effect may perhaps be dependent, as MM. Despretz and Savart have endeavoured to show, upon an actual combination occurring between the metal and some of the substances present; but whatever the cause, it may be taken advantage of without the necessity of having tubes formed of the materials, it being sufficient to introduce them into glass tubes in the manner before described for rock crystal (716); it will be found that a glass tube, charged with broken iron

turnings, will as effectually cause the decomposition of ammonia as one of iron.

718. The power of spongy platina is such that it occasions the combination of oxygen and hydrogen, even at common temperatures, producing ignition and explosion. When its action is diminished by mixture with earthy bodies, it is again increased by elevation of temperature. Spongy platina also causes the union of oxygen and oxide of carbon at common temperatures; the decomposition of nitric oxide by hydrogen; and the combination of both the elements of olefiant gas with oxygen, at temperatures above 572°.

719. The vapour of water passed over iron heated in tubes is decomposed, the metal becomes oxidized, and hydrogen gas is evolved. In this case, the higher the temperature the more rapid the action. The steam should be raised from a small boiler, and not in too large a quantity, as great excess tends to cool the tube considerably. If two-thirds or one-half of what is passed into it be decomposed, it is in sufficient proportion. The iron for small experiments may very conveniently be clean turnings, beaten into small pieces in a mortar. They lie close, expose much surface, and keep open a free passage for air.

720. The vapours of alcohol and ether may be decomposed in a similar manner: iron assists, but is not necessary; but rock crystal, or some substance affording surface (716) should be introduced. The results vary with the temperature. Nearly all the vapour that is sent in should be decomposed. It may be generated in a little boiler, or in a flask or retort, and caoutchouc junctions may be used, even with ether.

721. Olefiant gas, nitrous oxide, and some other gases, are decomposed by being passed through heated tubes. If in such experiments the general facts only are to be observed, the gases may be introduced from the retort evolving them, or forced in from a bladder or an air-tight caoutchouc bag (820, 821), and the contents may even be received in similar vessels at the other end of the tube: but if accurate

experiments upon precise quantities are required, then two mercurial gasometers (809) should be connected with the tube, that nothing may be lost.

722. Many oxides may be reduced in part, or entirely, when heated in tubes, by passing certain gases or vapours over them. Protoxide of manganese is best obtained in this way from a pure peroxide, or from the oxide precipitated from a pure salt: hydrogen passed over it at a red heat reduces every particle to the state of dry protoxide, and the progress of the change from one end of the tube to the other is beautifully exhibited. Oxides of titanium, tungsten, chromium, iron, &c., are often usefully treated in this manner; and besides hydrogen, other reducing agents may be used. Ammonia has equal power with hydrogen, and sometimes is superior to the simple gas. The vapours of alcohol, ether, naphthaline, and camphor, may be used, where it is probable that carbonaceous matter will favour the desired effect.

723. Many *combinations* are effected with great advantage in a heated tube. Thus oxygen is easily combined with baryta, and the peroxide of barium formed. The heat should be a dull red; no oxygen will pass till the whole of the earth is peroxidized. In such cases, the end of the tube at which the oxygen passes out does not require to be connected with any apparatus: a glowing match should now and then be applied to it, and when the presence of pure oxygen is evident, the operation is finished.

724. Sulphur may be combined with platina, and phosphorus with lime, in a tube apparatus, with great convenience. The platina in the spongy state, or the quick lime, are to be placed in the tube, and heated to dull redness; the tube should be slightly inclined, and the higher end lengthened so far from the furnace or lamp as to be only warm. If turned up, it is an advantage, and the aperture there should be fitted by a good cork. When the tube is sufficiently heated, a piece of sulphur in the one case, or a piece of phosphorus in the other, is to be dropped or thrust in at this end, and the aperture immediately closed by the cork. A small spirit lamp flame will melt the substance, and cause

it to run down to the warm part, where it will gradually become vapour; and though a part may distil back (which is of no consequence), the greater portion will be sent over the platina or lime within: the progress of the change will easily be observed. When the first portion of substance has combined, a second is to be introduced; the aperture being rapidly opened and closed, so that no current may be allowed to occur in the tube, and this process is to be continued until the substance within is entirely converted into sulphuret or phosphuret. Great care is, of course, required in handling the phosphorus; pieces not more than one-third or the half of an inch in length, should be introduced at once into tubes half an inch in diameter. They should first be dried, then dropped in rapidly by a pair of forceps, lest the temperature of the tube should be sufficient to inflame them. In wiping phosphorus dry, it should be rolled between two or three folds of cloth or filtering paper, every part of its surface being pressed but not rubbed; and when thus dried, it must not be held in the uncovered hand, but be inclosed in cloth or paper, and be taken out from them by the forceps. This is to be done at some little distance from the furnace or lamp, and when the phosphorus is carried towards the heat, the operation should be conducted quickly, though steadily, that no time be allowed for the temperature of the substance to rise so high as to cause its inflammation before it be in the required situation.

725. Titanium may be combined with chlorine by passing the gas over the metal in a heated tube. The alkaline earths may be decomposed by passing chlorine over them in the same manner, oxygen being then evolved, and their bases remaining combined with the chlorine: numerous other chemical actions of the most important kind may be effected by this mode, in a manner the most convenient possible for observation. When the substance used and the results produced are equally fixed, small platina trays, formed by doubling a piece of foil, may be used for containing them; they are easily introduced into the tube, and withdrawn again by a wire bent into a hook at the extremity. Every facility is afforded for conducting away the

results, whether solid, fluid, or gaseous; and in by far the great number of cases, those excellent flexible connectors formed of caoutchouc (449) are of perfect and easy application.

SECTION XV.

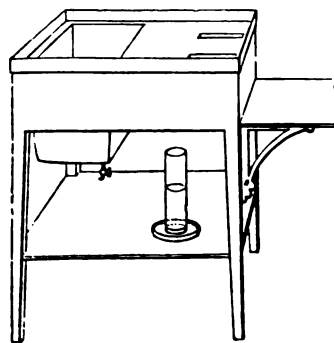
PNEUMATIC MANIPULATION, OR MANAGEMENT OF GASES.

§ 1. *Pneumatic Troughs, Jars, &c.*

726. THE first apparatus necessary for the experimental practices to which this chapter relates, is the pneumatic trough, with its accompanying jars. We are indebted to Priestley for the invention of this useful vessel, and for much of the apparatus which is used in conjunction with it.

727. The common pneumatic trough is a vessel constructed so as to retain water, and of such dimensions that large jars may be filled in it; and it is furnished with shelves or supports beneath the surface of the water, on which vessels may firmly stand. The trough is frequently so contrived, that the shelf is of considerable extent, and the deeper part, which may be called the well, made of such dimensions as just to allow the filling of the largest jar required for use. This is of no consequence as regards the level of the water, and its alteration by filling jars, and raising them upon the shelf; but it is of importance that the well should be sufficiently large. There should be width and breadth enough for two or three jars to be immersed at once, and sufficient depth to permit the inversion of any jar or tube beneath the surface, likely to be in use at the trough. The shelf also of the large trough should be of sufficient size to hold several jars of gas at once. If the surface of water be 19 inches by 28, and a well be formed at one end of 14 inches by 10, and 12 inches in depth, so as to leave a continuation of the shelf surface on three sides of the well, of two inches and a half in width, it will be found sufficiently large for almost every purpose.

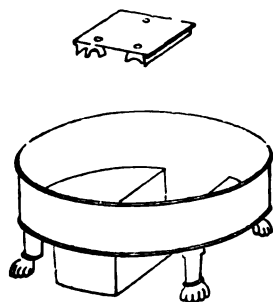
728. Such a trough is best made of japanned copper, and supported in a wooden frame, so as to stand about 39 inches from the ground. Two depressions, like small wells, should



be made in the shelf, each about seven inches long, two wide, and one and a half deep. They should be placed with one of their narrowest ends about one inch and a half from the end of the shelf which is furthest from the well, and about eight inches apart. These depressions are to receive the beaks of retorts delivering gas into jars placed

over them; and it is advantageous to have a flap fixed to this end of the trough frame, which, turned up or down at pleasure, may be used when there is occasion to support a retort stand, or other apparatus required in the evolution of gas. This trough should be filled with water until it is one inch and a quarter or one inch and a half above the shelf. A stop-cock should be fitted into the bottom of the well, by which the water may be drawn off when it has become acidified or dirty.

729. These principal troughs are sometimes made of wood,



but never with advantage, because of their complexity of form, and the consequent difficulty of keeping the numerous joints tight. They are often on a smaller scale, and when the chemical establishment altogether is small, are then more in proportion to the rest of the apparatus. A very useful table trough is of a circular form, and about two feet in diameter, internally divided into

three parts; the middle part is seven inches deep, and forms the well; the other parts on each side four inches deep, and are the shelves; a moveable shelf, with holes in it, extends

from side to side across the well, and serves to support such jars as are receiving gas from the beaks of retorts placed under the holes.

730. Besides a principal trough, several smaller ones are required for the preparation of particular gases, as, for example, chlorine, when warm water is required; or sulphuretted hydrogen, which contaminates water, and would discolour metallic troughs. These may be either of metal or earthenware, and need not have fixed shelves. An earthenware foot-bath makes an excellent trough; and even a wash-hand basin, or moderately sized evaporating pan, is at times sufficiently large, very portable, and offers advantages.

731. Trivets are used with these smaller troughs to support the jars. They are best made of cast iron, in the form of very open grates, either square or round, and raised by means of three or four feet; they should be of different heights, from half an inch to two inches, and when very dry should be covered with a good coat of black varnish, or made hot almost to visible redness, and then brushed over with oil; the oil is in this way decomposed, and leaves the metal covered with a very permanent varnish. These trivets answer the purpose of shelves when required, and also support the jars when filled with water, so that the beak of a retort, or the end of a tube, may be introduced beneath them.

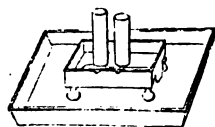
732. When the small troughs are used, so much water must be present as at all times to cover the trivets an inch or more in depth. Small and narrow jars may be filled in them with water, but larger jars are generally filled more conveniently at the large trough, or in a pail, and then transferred in the manner to be shortly described (751). If during their use the water rise so high in the troughs as to endanger the steadiness of the jars containing gas standing in them, a part must be removed. The facility with which extemporaneous troughs may at any time be contrived, will be evident from what has been said relative to these smaller arrangements.

733. Water which has been taken from a deep well, from a cistern into which it has been thrown through the exertion

of much power, and from other situations, frequently contains so much air in solution as to interfere with the purity of gases standing over it in the pneumatic trough; for when in the smaller quantities it is relieved from the pressure and other circumstances which favoured the absorption of air, and now evolves it again in numerous bubbles. Hence water which presents this appearance to any extent when put into the trough should be avoided, or else its probable influence should be remembered, that upon particular occasions it may not, through inadvertence of the operator, introduce inaccuracy into pneumatic experiments.

734. Water troughs are calculated for the reception and retention of gases not soluble, or alterable by water, but not for the many which are affected by that fluid. Dr. Priestley was the first who recommended the use of mercury; and though its weight and opacity are disadvantageous, that metal is still so superior to any thing else, as to be constantly used in these cases. Being expensive as well as heavy, it is necessary that the troughs in which it is used should be as small as possible, consistently with the performance of experiments, and at the same time of a material that will resist the action of the metal. They have been made of wood and of marble, but varnished cast-iron, which is now generally adopted, is by far the best substance. In principle and in the arrangement of the parts, they resemble water troughs. Newman's large mercurial trough will allow the use of a jar two inches and two-tenths in diameter, and nine inches in length; it has seventy-six square inches of shelf room very well arranged, and also a mercurial gasometer attached to it at one extremity. It requires from 60 to 70 lbs. of mercury for the free performance of experiments.

735. Newman has also a much smaller trough for the use, though in a confined manner, of jars 1.5 inches in diameter, and six inches in length; it has only thirty square inches of shelf room. It requires 20 lbs. of mercury to fill it, with a jar standing on the shelf. When working with jars of gas over this trough, the metal requires transferring back-



wards and forwards, because of the difference in level made by the descent or the elevation of a jar-full; but the trough is nevertheless very useful in operations on small quantities, either in tubes or small jars.

736. A mercurial trough should always stand in a tray, and likewise have a cover to keep out dust and dirt, when not in use. Its place, as before described, should be upon the table grooved round the edge (12), that waste of mercury may be avoided as much as possible. When the metal is spilled it is best collected by being swept together, and then gathered up by a card. A card will even gather it well up from the surface of baize. If only occasionally in use, it is better to keep the mercury in stone bottles, than by constant exposure in the trough to render it liable to accidents and loss.

737. The jars which accompany, or are required with, pneumatic troughs, are of various kinds. *Plain jars* should be from twelve to sixteen inches in length, two and a half or three inches in diameter, of such thickness (about one-eighth or one-tenth of an inch) as to withstand the general liabilities of use, and ground at the edges, so as, when moistened or greased, to be closed accurately by a flat glass plate. Those for the mercurial trough should be from four to eight inches in length, one and a half or two inches in diameter, and as thick as the former, that they may safely bear their weight of metal when filled and in use. These also should be ground at the edges.



738. *Stoppered jars* have an aperture above, fitted with a ground-glass stopper, and resemble stoppered bottles without bottoms. They are required of different sizes, and should be larger in diameter than the plain jars; the proportions may be gathered from the figure in the preceding wood-cut. Such as are less than three inches and a half in diameter should be ground at the lower edge, and all ought to be ground flat at the top, for the convenience of closing them occasionally by a glass plate (1348), instead of the stopper. It is useful in public laboratories, and often in private ones, to have a second set of stoppers for several of

these jars, the stoppers having a projecting knob beneath, to which a deflagrating spoon, or a taper, or other article, may be attached by a wire. When it is required that any one of these should be introduced into the gas already confined in a jar by the first stopper, it is to be attached to the second, and introduced rapidly after the removal of the first stopper, and the jar closed by the stopper to which it is suspended. When these second stoppers are not at hand, corks will often answer the purpose very well, the wire which supports the article introduced being thrust through them : but being combustible, they will not answer for deflagrations in oxygen gas, unless their lower surfaces be previously guarded by a plate of sheet lead or iron. In all deflagrations the spoon or combustible should for many reasons be put as low down in the jar as possible. A good cork will occasionally form a very tight and excellent stopper to an open jar which has not been ground.

739. The stoppers of jars, and indeed all ground-glass stoppers, should be of considerable thickness where the lower and upper parts are connected : for sometimes considerable strength is required to loosen them from their places, in consequence of difference of temperature, the hardening of some substance around them, or other circumstances. For the method of loosening stoppers thus fixed, see Sect. xx. (1263.) Stoppers should never be put into pneumatic jars without having been previously touched by a little pomatum or tallow (433), so as to make them fit easily but closely, and this should be renewed whenever from use or cleaning there is occasion for it. Neither should they be put into jars or bottles in a heated state ; the latter frequently then contract on the stoppers, and it becomes almost impossible afterwards to move them.

740. *Capped or transfer jars* are such as, being open above, have a cap cemented upon them, the latter being surmounted by a stop-cock. They allow of easy communication with other apparatus, by adapters and screws. They should be of three or four different sizes, and a large and a small one should be graduated. A small capped jar or two



should be provided for the mercurial trough, of the dimensions before given (734). These jars should often be examined, to ascertain the tightness of the cap and stop-cock, by which they are closed. This is best done by nearly filling them with water or mercury, according to the trough to which they belong, without moistening the stop-cocks, placing them on a steady part of the trough, observing where the level of the water or mercury stands inside, and leaving them for half an hour or an hour. If at the end of that time the level be unchanged, the jar is tight, and in that respect in order.

741. The lipped glasses before described (368, 505), both large and small, are very useful as jars when operations are carried on at the small troughs, or with small quantities of gas; and tubes closed at one end will frequently be required for the same purposes. These tubes may be of any length less than 10 or 12 inches, and of any diameter; some may be plain, but several should be graduated (127), for the estimation of small quantities of gas. Those which are too wide to be closed perfectly by the finger, should be ground at the edge so as to be closed, when required, by a glass plate (1348). The others should be level, or nearly so, at the mouth, and not irregular from bad cutting or from fractures.

742. None of these vessels when cracked should ever be used at the mercurial trough, for they are not only rendered very weak and are easily destroyed by a slight blow near the cracked part, but often suffer the gas to pass slowly through the fissure. They should rarely be used at the water trough, except in very common experiments; for, notwithstanding cracks when moistened are frequently airtight, though not so when dry, yet they as often leak, especially when the water does not adhere to their surface, or when the gas within is subjected to those sudden movements which frequently occur in experiments; besides these risks, the jars are easily broken, and the gas consequently lost.

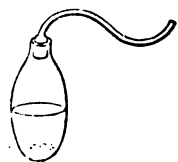
743. In addition to the vessels already described, small and moderately-sized funnels, with narrow necks, will be required to assist in the transference of gas into vessels

having narrow apertures; and dishes will be necessary for the removal of jars containing gas from one place to another. These dishes may be of glass or earthenware, as evaporating dishes (369); or of metal, being then best made of sheet copper, with a flat bottom and upright edge. Even common soup or dinner plates and tea saucers will answer the purpose extremely well. The glass plates before referred to (738, 1348), are in constant use in closing the mouths of such jars as, not being too large, have ground edges.

§ 2. *Production, retention, and transference of Gases.*

744. The manner in which gas is evolved is very variable. It is frequently, liberated during distillations in iron, earthenware, or glass retorts: these processes have been described, and all that is now necessary to be referred to is the fact, that such apparatus must terminate in a beak, which may either be directly plunged into the fluid of the pneumatic trough, or lengthened by a tube which may have its extremity placed in a similar situation. Gas is sometimes produced by tube operations (704, 716, &c.), and the manner of leading it away by tubes to the trough will be evident.

745. When the liberation of gas takes place at common temperatures, and immediately the materials are in contact, as of hydrogen from diluted sulphuric acid and zinc, or of carbonic acid from muriatic acid and pieces of marble, then glass retorts are sometimes used, and on other occasions gas bottles and flasks. The adaptation of retorts to these purposes is simple and evident. Gas bottles are vessels intermediate in their character between flasks and bottles, being



thickened at the neck and having pieces of bent tubes fitted to them by ground joints; the bottle therefore represents the body of a retort, and the bent tube the neck. When the materials are introduced, the tube is put into its place, and its open extremity immersed in the water of the pneumatic trough. When a common Florence or white flask has to perform the office of a generator, it must have a piece of bent tube fitted to it

by a good cork (484), and this will answer every purpose required.

746. The open neck or tube by which the gas is ultimately delivered, whether it belong to a retort, a tube apparatus, or a complicated arrangement of vessels, is to be immersed in the water of the pneumatic trough. When the vessel is a mere retort or gas bottle, it is easily arranged in a convenient situation, being supported in its place by a stand (386); and moveable apparatus of any kind may generally be arranged on a table near the trough, so as to have the necessary juxta-position. If from circumstances the apparatus disengaging gas is fixed, and cannot be brought to the trough, as may happen for instance in the distillation of oxygen gas in an iron retort, or in complicated experiments of research, then either the neck must be prolonged by connecting tubes of glass, or small pneumatic troughs must be used; these, being portable, may easily be placed in the vicinity of the apparatus. It is often necessary in these cases to collect large quantities of gas over a small trough; and this is easily effected, by transferring the jars (751, 756) as they are filled, to the larger trough, and replacing them by such as are filled with water.

747. A prime object in preparing gases is generally to collect the pure portions only; and it becomes necessary to expel the common air of the retort or gas bottle, before the particular gas is collected. For this reason, the first portions may be thrown away; but as a general rule, it is better that these should be collected in a jar, and then rejected, rather than, by leaving the beak of the retort exposed to the air, to allow them to escape at once into the atmosphere. By collecting them, it is known when twice or thrice the contents of the retort has passed out; after that, the gas may be collected for use: by suffering them to escape from the beak, the estimation of the quantity rejected, and the probability of the air being all displaced, is vague and uncertain. When a quantity of gas has been allowed to escape, sufficient to justify the opinion that what is afterwards evolved is nearly or quite free from air, the future portions may be collected in jars for use, as is immediately

to be described; but the order of these jars should still be attended to, for which reason it is well to mark them one, two, three, four, &c., as they are filled, and then, in case a portion of gas perfectly free from atmospheric air be required, the third or fourth jar may be resorted to instead of the first or second.

748. On other occasions it is important to collect *all* the gas that may be evolved, that its quantity may be measured. It is then frequently necessary to collect every bubble of gas that comes from the retort, including the common air itself. Then, after having estimated the whole of the gaseous products, the capacity of the retort, and the volume of solid or liquid matter it may have received as a charge, it becomes easy to ascertain the volume of air, and consequently the volume of pure gas evolved. In this case the jars are to be numbered as they are filled; for though the first contains much atmospheric air, and perhaps also the second a little, the others are filled with a pure gas, which may be preserved for use. The operation of collecting and estimating the whole of a gas is delicate, and requires considerable variation, according to the nature of the gas, and the bodies from which it is to be evolved. These points would be improperly introduced into the description of elementary operations, but will be referred to again in a more advanced part of the volume.

749. The trough being filled with water as before described (727, 732), and the apparatus arranged ready for the evolution of gas, a jar is to be selected, which we will consider for the present as a plain one (737), and being immersed in the water of the trough with its mouth inclined a little upwards, so as to allow the air to escape, is to be filled with water. It is then to be raised upright, with its mouth downwards, and will be found to remain full of the fluid, so long as the mouth is retained beneath the surface of the water; it may in that situation be placed upon the shelf of the trough, or upon a trivet. If placed over an aperture in the shelf, or with its edge projecting a little way over the well, there will be no difficulty in so arranging the beak of the retort, that the bubbles of gas escaping from it shall

ascend into the jar, and, accumulating at the top, gradually displace the water, which will descend and mingle with that in the trough. When the jar is nearly full of gas, a second is to be depressed in the well of the trough, filled with water, and placed on the shelf by the side of the first: when the gas in the first is within half an inch of the mouth, it is to be moved on one side, the second put into its place, and filled in like manner with gas. Or if the retort or vessel be moveable, and the jars large, it will be better to place the second jar over another aperture, or projecting conveniently over the edge of the shelf by the side of the first, and to transfer the beak of the retort from the first to the second, rather than to endeavour suddenly to move them: then, after displacing the full jar, the final adjustment of the retort and second jar may be leisurely made. In this way jar is to succeed jar, until the action in the retort has ceased, or until sufficient gas has been collected.

750. The filling of the jars with water in the well of the trough must be so conducted that none of the air passing from them shall enter into the jars already filled with gas. For this reason, when a jar is full of gas, it should be put so far upon the shelf, that its mouth may be entirely closed; and in filling the fresh jar with water, its mouth is to be turned away from the gas jars already in use. The mouth of a jar is not to be immersed first, so as to cause the air to burst forth in large bubbles; but the closed end should be first depressed, and the water suffered to flow in, and the air to pass out, smoothly.

751. If the trough in use be a small one, there may not be shelf room in it for the jars as they are filled, in which case it will be proper to transfer them to another place. For this purpose an evaporating or glass dish, or a common plate (743) is to be selected, of sufficient size freely to receive the mouth of the jar, and allow water to remain around it; this dish is to be put into the water about an inch beneath the surface, and the jar moved until its mouth is received into it; this being done, the jar and dish are to be raised together out of the trough, and placed safely on one side. The water in the dish will confine the gas, just

as well as the water in the trough, the dish in fact becoming a small trough for the time; all that is necessary is, to preserve the portion of water which accompanies the jar at such a height that the mouth of the latter may never be uncovered. Very little depth of water is required; so that this point be attended to, a common kitchen plate will answer the purpose exceedingly well. The jar of gas thus removed may either be left in that state, or may be transferred to another trough by immersing the dish and mouth of the jar into the water of the second trough, and then removing the dish.

752. Sometimes, also, it will happen, from the smallness of the trough, that there is not room to fill the jar with water. It may then be filled in a pail, or in the large trough, and transferred in the manner just described, by means of a plate or dish, to the trough at which the gas is to be liberated. The long jars already described (737), which are ground at the ends, are very advantageously transferred by the help of a glass plate (1348); which dipped into the water and held tightly against the mouth, is in its moistened state quite secure, and will safely retain the contents of the jar during transference, whether they be water or gas, or both.

753. Such is the manipulation with plain jars: it is the same with stoppered and other vessels, except in occasional variations in the mode of filling them with water. A stoppered jar may be filled with water by removing the stopper, depressing the jar in water in an upright position until entirely immersed, and then replacing the stopper: it may be afterwards raised and used as a plain jar. Transferring jars, or such as having a cap cemented to their upper aperture, are finally closed by a stop-cock (740, 827), frequently require to be filled with such care as to avoid the introduction of any water into the stop-cock. This may be done by sinking the jar steadily in water, allowing the air to issue out at the cock, until the fluid has risen into the cap, and very nearly as high as the aperture of the cock itself; then, by closing the latter, the water is retained in the jar.

754. When there is not sufficient depth of water in the trough to admit of this process, another method may be adopted. It is to apply the lips to the upper end of the stop-cock, and to withdraw the air by the force of the lungs and mouth. This may be done at one, or at several times, a clean cloth being placed over the stop-cock to prevent its contact with the lips. As the water approaches the cap, its ascent should be moderated, and when within a very small distance of the cock, it should be arrested altogether by closing the latter.

755. It is evident that these transfer jars cannot be filled with water by inclining them in the trough, without introducing the fluid into the stop-cock, although its entrance may be excluded from the upper half by closing it with the finger. When filled with water, they ought to be moved with care, lest any portion should be thrown up into the stop-cock; and when placed to receive gas, the first bubbles should be admitted with equal caution, one by one, or as they break within they will splash the liquid into the aperture above. When the fluid has descended below the cap, so as to be in sight, there is but little danger of this happening, and the operation may proceed more rapidly. If pure gas is to be collected in these jars, it is necessary that the first few bubbles should be expelled through the stop-cock, that they may carry away the common air from it; this expulsion is effected by sinking the jar up to the neck in water, opening the cock slowly, and refilling the vessel with fluid. It can only be done in a trough or vessel deep enough to allow of sufficient depression.

756. During the collection of gas in a small trough (746), the jars being filled at another place with water (752), there is of course a rapid alteration in the height of the surface of the water in the trough, from the continual addition of that fluid from each jar. In such cases it is necessary to lade the water out, and to return it to the vessel from whence it was taken, and from which the jars were filled. Considerable care is sometimes required on this point, in order that the level of the water may not rise too far above the surface of the trivet or shelf. If the depth of water be inadvertently

allowed to increase, and at the same time the gas be permitted to collect in the jar until the latter is almost full, it will frequently happen that the jar, becoming buoyant, will fall over, and its contents escape. Jars, generally, should not have the water depressed to within less than half an inch of their edges, the level within being then nearly the same as that without.

757. After having succeeded in collecting gases over the trough, the next facility to be acquired is the decantation of them from one vessel to another, either in large or small portions, or with vessels of different sizes. In decanting gas from jar to jar, which is the simplest case of this kind, the operation is easy, and in reality is only an inverted pouring, the gas or air being poured upwards through water from one vessel to the other. The jar into which the gas is to be introduced, is to be filled with water, and placed in the usual way with its mouth upon the shelf of the trough, as if it were to receive the gas from a retort; it is then to be brought forward over the well, removing two-thirds or three-fourths of the mouth from off the shelf, so that though the jar is supported by one edge, another jar may with ease be brought towards it, and turned up beneath its mouth. This done, and the jar retained steadily in the left hand (that being usually most convenient for the purpose), the second jar (containing the gas to be decanted), and which must previously have been placed on the shelf of the trough, is to be brought forward by the right hand, and, being depressed in the well, is to be approximated to the first jar, and inclined so that, while its mouth is elevated in relation to the closed extremity, it may be made to pass under the mouth of the first jar, in order that when the gas, because of the further inclination, issues out in bubbles, it may ascend into the latter. The top of the jar to be emptied is then to be depressed until the whole is under and full of water, but this must be done gradually and steadily; the gas not being suffered to pass out suddenly, or in large quantities, for then the magnitude of the bubbles causes them to interfere in their ascent with the descent of the water, and portions are frequently thrown outside.

758. In all practice of this kind, the experimenter should endeavour to obtain a habit of steady and successful manipulation; and even when care may not be required for the particular experiment, he should be anxious to acquire dexterity, that when it is of importance, no chance of failure may be incurred. When the form of the trough is that described (727), it is advantageous to bring the jar full of water over the corner of the well, for its weight is then more safely supported by the two sides of the shelf above, and the mouth of the jar whose gaseous contents are to be transferred, may more readily and certainly be conducted beneath the first jar, by means of the angle existing in the well.

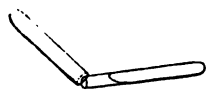
759. When the gas is to be transferred from large into smaller jars, or into bottles, more care is required than in the case just described. A jar with a large mouth delivers bubbles of considerable lateral extent; and when these rise towards an aperture, it is to be remembered they cannot enter it, unless there be space for the passage outwards of an equal bulk of water at the same time; if there be not, they will frequently be broken and part of the gas be carried outside and lost. In these cases funnels are highly useful, and especially in filling bottles: a funnel, being inverted and immersed in the water, is to have its beak introduced into the mouth of the bottle filled with water, and the gas, being decanted into the funnel, is readily and safely conducted into its proper place. The difficulty of the operation is at first increased, because attention is to be given to the funnel and the bottle at the same moment; for the former and the mouth of the latter must both be retained under water, and the edge under which the jar is to be brought is necessarily much deeper in the trough than if no funnel had been used.

760. Instead of a funnel, a lipped jar or glass (368) may be employed in the transfer as an intermediate vessel. These, although they have wide mouths, deliver narrow bubbles of air by the lip, and to that owe their advantages. All that is requisite is, to bring the lip into such a position that, as the jar or glass is inclined, the lip may be the

highest part of the mouth, and the gas consequently tend to flow out there.

761. The manipulation with jars and glasses is comparatively easy to that which occurs in transference of gas from them to tubes, or from tubes to each other; and yet this latter practice is continually required in the laboratory, especially in eudiometrical and analytical operations. One circumstance with tubes which occasions difficulty, in addition to the narrowness of their mouths, is, their contracted capacity within, by which the easy passage of a bubble of gas upwards, and water downwards, at the same time, is interfered with; this effect is greatest in tubes of the smallest diameters.

762. No great difficulty will occur in the transference of gas from a tube to another that is wider. The second tube is to be filled in the usual manner with water, and held in the well of the trough, in a considerably inclined position;



the tube containing the gas is to be brought near it, the upper edge of its mouth inserted as it were into the mouth of the first, and then its position slowly altered, until the gas passing towards the mouth be gradually delivered in distinct bubbles into the first tube. During this transfer, the mouth of the second tube should be retained as much as possible within the first; the latter should not be raised to a perpendicular position, but be considerably inclined, for then the edge of its mouth meets better with, and is adapted to those of the second tube, so as to confine the gas, and the motion of the bubbles is less sudden and less subject to derangement. Occasionally, it is advantageously placed in almost a horizontal position, its closed extremity being but little raised. One bubble of gas should be allowed to rise to some height in the tube before another is permitted to follow.

763. When the delivering tube is larger than the receiving tube, more care is required in the transfer. The first tube should be inclined as before, and the upper edge of the mouth of the second placed within it; and to assist in uniting as it were the two tubes for the moment, the finger

and thumb of the left hand (which holds the receiving tube) should be applied at the sides of the junction, so as to confine the gas and prevent its escape laterally. For this purpose, and generally indeed in tube transference, the tube is best held in the hand, with its open extremity passing out between the thumb and fore finger, so that when sustained in the water in an inclined position, the back of the hand may be upwards, the hand being as it were over the vessel; the tube is then easily supported by the two or three last fingers of the hand, and the fore finger and thumb are left at liberty to guide the mouths of the vessels, or to close the lateral opening, as has been just described.

764. At other times it may be held as a pen is retained in the hand, the mouth being confined and guided between the thumb and two fore fingers, but there is then less facility in elevating or depressing it to different angles. The tubes should at all times be retained by a light and easy, though secure hold, and not in a stiff rigid manner, and the arms may often be allowed to rest with advantage on the edge of the trough, whilst the hands are immersed in the water.

765. An intermediate lipped glass should be used for the transference of gas from a large jar to a tube. No difficulty will be found in transferring from a lipped glass to a tube. The tube being filled with water is to be held under the surface, as before described (762); the lip is to be introduced into it, the junction made by the fingers if necessary, as in the former case, and the gas allowed to pass in distinct bubbles. It will be found easier to transfer from a glass that is from a third to five-sixths full of gas, than from one containing more or less. When a glass is nearly empty, it is often exceedingly difficult to transfer from it into a narrow tube. Advantage may, therefore, occasionally be taken of the circumstance above mentioned, by replenishing the glass with gas.

766. Finally, small funnels may, when requisite, be used for the transference of gas into tubes, the procedure being exactly the same as that before described (759). Tubes containing gases are easily transferred from one trough to

another, or to other situations, merely by closing their mouths with the finger or thumb, and carrying them to the required situation. The student should very early attain the habit of closing the mouth of a tube by the finger with facility and security. The accurate manipulation of gas in tubes, so that none shall escape and be lost, is often essential in experiments of research, where only small portions of gas are evolved, yet require to be examined as to many properties.

§ 3. *Measurement of Gases.*

767. There are two cases of the measurement of gases. Either a bulk of gas is to be accurately measured, or the separation of a certain volume from a larger quantity is required. The mode of determining the bulk of gas received in a plain jar may be first considered. The jar must stand steadily on the shelf of the trough; three pieces or slips of waxed or oiled paper are then to be attached by a little wax (1125) and slight pressure, at equal distances on the outside of the jar, so that they may just adhere, and serve to mark the height of the water within, by their upper edges. The jar is then to be removed from the shelf and depressed in the well until the surfaces of the fluid within and without coincide, and the operator should observe how far this change of position has altered the coincidence of the three pieces of paper with the surface of the water within, taking care that the jar be held upright during the observation, so that any difference may be the same at each mark. The jar should then be replaced upon the shelf, and the situation of the paper marks raised by a quantity equal to that which it was observed they were too low, when the gas was levelled. This may easily be done by the eye, the elevation of the marks being made now just as much above the gas within, as they were too low when the jar was depressed in the well. The jar should again be sunk in the well until the inner and outer surfaces of the fluid are level; the correspondence of the marks with the level should be observed, and the process carried on in this manner until the adjustment is perfect: the papers are then to be pressed

more forcibly against the glass, that their adhesion may be secured. The gas is now to be transferred (757) into a graduated jar (740), to be depressed also in the well until the inner and outer surfaces of the water being level, the gas within may be subject only to the pressure of the atmosphere; the graduation is then to be observed, and a direct determination immediately made of the quantity of gas contained in the jar.

768. In this operation the jar should be held perfectly upright, and the use of the double or triple graduation before recommended (119, 150) will be evident, from the facility with which it is now ascertained by inspection, whether the jar is in its right position, and, consequently, whether the determination by the different graduations accord, as ought to be the case; if not, they may easily be made to do so by inclining the jar a little one way or the other, and the volume should not be considered as ascertained until both or all the scales agree.

769. In reading off the height of gas in jars, and also in adjusting the paper marks already referred to, the observation should be taken not from any part of the curved surface of the water close to the glass (122), but from the general and undisturbed level within; and when, in equalizing the pressure within and without the jar, that surface is necessarily brought low and beneath the level of the eye, the student should not be satisfied with a casual and oblique glance, but should also lower his eye and bring it as nearly as possible to a level with the surface itself. When the jar is thus lowered in the well, without resting anywhere upon its edge, and sustained only by the hand, great assistance and steadiness may be gained by holding and pressing it as it were into one corner of the well, sustaining it in part by friction against the sides: further assistance may be gained also by supporting the wrist or arm on the edge of the trough.

770. If an accident happen in transferring the gas, or afterwards in the graduated jar, before the volume is ascertained, a record of the quantity is preserved by the three waxed paper marks (767), and hence their great use: if no

accident happen, they still serve to verify the measurement. For the latter purpose the jar is to be removed from the trough, set with its mouth upwards, and then water measured in (121), until it is filled by that fluid to the extent that it before was by gas. If the quantity of fluid thus introduced accord with the measurement of the gas, an assurance is gained of the accuracy of the determination.

771. When the gas is collected in the first instance in a graduated jar, it may of course be measured in it, as has just been described, transference being then avoided; hence an advantage, in many cases, in receiving gas, requiring to be measured, directly in such jars.

772. If the gas to be measured is contained in ungraduated tubes, the process, though a little varied, is the same in principle. The level within and without is to be equalized, and the height of the gas marked with a file (132), or by a slip of waxed paper put round the tube like a ring. The gas is then to be transferred into a graduated tube (741), levelled (769), and its volume determined by the graduation. Both in the marking and observing, particular attention is to be paid to the curve of the water, for the considerations which were formerly insisted upon (135), as important in graduating, are now equally important in observing. The practice there mentioned of always reading in the same manner should be particularly attended to (122), and by a little experience the point on the graduation, which may be considered as that which would coincide with the surface, supposing the gas and water to meet by a plane, may be ascertained very accurately from mere inspection. The tube in which the gas was first contained, and which was marked by the file or paper, may afterwards be measured up to the mark by water or mercury from a graduated tube (125, 127); or if very small, the mercury may be weighed, the precautions with regard to convexity of the surface not being forgotten (135).

773. In all estimations of the bulk of gas, the temperature by the thermometer, and the pressure as indicated by the barometer, should be observed and registered in the laboratory note book (1290). No considerable difference

should be allowed to exist between the temperature of the air and water at the time of the experiments; if it be more than a degree or two, it should be corrected by altering the temperature of the water. The registered temperature should be that of the water; and great care should be taken in handling the jars, that their temperature be not made to differ from the observed one. For this reason they should be held lightly by the thick part of the neck, and not grasped at the sides, lest a temporary change of temperature, and consequently of volume, should be induced, which in certain cases might occur just as the volume of the gas was under determination. The barometer should be an accurate one, or, if inaccurate, the difference in altitude between it and a perfect instrument should be known, and always allowed for, as a necessary correction. In observing this instrument it should be supported perpendicularly, the eye being level with the surface of the mercury; it should be observed whether the mercury be concave or convex, and after having observed its height, the instrument should be slightly tapped to allow free motion to the metal, until tapping produces no change. If the experiments are long, the barometer is to be observed two or three times during their continuance, that no unperceived alteration may occur to vitiate the results.

774. In *measuring out* a required quantity of gas, no difficulty will occur with large quantities. A graduated jar is to be filled with water, and the gas passed into it (757) until there be nearly enough. The additional portions are then to be added more carefully, at first from a lipped glass (765), and when the quantity is almost sufficient, from a tube. The water within and without the jar is to be brought to the same level at every examination of the bulk on the scale. Many depressions of the jar in the water, for the equalization of pressure, will not be required, a facility of adjustment being obtained by attending to the quantity apparently necessary when the level is so equalized. Thus, if it is found when the jar is depressed that the level of the water within is one division higher on the scale or graduation than it ought to be, then on raising it to the shelf, gas

is to be added until the level is depressed by one division, without respect to the particular part of the division with which it may happen in that state to coincide; upon restoring the equality of level, the quantity will be found very nearly accurate, and the portion that is necessary to make it quite so, may now very well be estimated, and accurately added at the next trial.

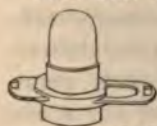
775. The advantage of using the tube for the addition of the last portions is, that much smaller bubbles may be delivered into the jar, and the final adjustment be more accurately made. If the aperture of a tube at the trough containing gas be closed by the fore finger (of the right hand), whilst it is held by the thumb and other fingers, and inclined under the water, with the mouth upwards, so that the gas within would escape but for the finger, then if the finger be relaxed a very little at the lower edge, so that a small quantity of water may flow in, and the mouth be immediately closed as before, it will be found that at each operation a bubble of air will be expelled from the tube, the dimension of which will depend on the degree in which the finger was withdrawn, and on the quantity of water consequently admitted. In this manner bubbles smaller than a pin's head may be obtained, and consequently a very minute quantity of gas may be added; whereas risk of adding too much in one large bubble is incurred, if the gas be let out from a tube not thus guarded by the finger, or from a glass or jar.

776. In measuring quantities in tubes, for eudiometrical and other experiments, more care is required than is usually necessary with large quantities, because general proportions and results are frequently deduced from very small volumes. In these cases standard or unit measures are often useful, and being equally filled again and again, afford a series of equal volumes. In filling them, however, it is not sufficient that gas be passed into them until they overflow, for from the cohesion of the water, and other circumstances, this will take place when the measure contains very different quantities, and it will in almost all cases be rather more than full, the gas projecting beyond the edge of the tube. When

therefore such measures are made out of tubes (142), it is usual to close them when full of gas by the finger, the excess being thus thrown off; but inasmuch as the skin, when dry or soaked, or when slightly or forcibly pressed, enters more or less into the opening of the tube, an inaccuracy is occasioned unless the operator be careful always to make the applied part of the finger assume the same convexity, and the measure used be of small diameter. With these precautions, this is a very good mode of measuring. These tubes are sometimes closed by stoppers, so adjusted as to leave a capacity of the proper measurement, and occasionally larger measures, amounting to the half or the whole of a cubic inch, are made of bottles carefully stopped and adjusted for the purpose (125).

777. In using measures of this sort a surplus of gas is to be introduced, the stopper put into its place, and the excess thrown out; but in introducing the stopper it must be done in such a manner as to exclude water as much as possible from the measure. It should be introduced at first obliquely, one edge being a little higher than the other, whilst the measure itself is quite perpendicular. It should be observed that the gas descends on all sides of the stopper, or at least that no large quantity of water is carried up on one side; and this being the case it may be thrust into its place, the extra bubble of gas thrown off, and that within the measure used as required. If the measure be inclined, and the stopper put in carelessly, it will be found in most instances that a quantity of water has been carried up into the bottle or measure, on the bottom of the stopper, notwithstanding the considerable excess of gas that was first introduced.

778. Mr. Cavendish used a measure for these purposes, consisting of a piece of glass tube closed at one end and fitted into a brass collar, with a flat slider passing through it; this, when thrust forwards in a direction at right angles to that of the tube, closed its mouth, and included a space accurately adjusted to half a cubic inch. When used, the slider was opened, and a surplus of gas passed into the tube, the slider was then closed, the excess of gas beneath



it thrown away, and the included and accurately measured volume retained for use.

779. When, in consequence of the nature of the experiment and of the measure used, the operation does not consist in accurately filling a measure or tube, but in filling it to a certain mark only, as for instance, to the fifth or the tenth division on the graduation (and in general this will be the kind of measurement required in tubes), a little excess of gas above what is wanted should be put into the tube, and the adjustment effected by closing the mouth with the finger, and letting out minute bubbles in the manner just described (775). The tube is to be returned to an upright position occasionally, and the quantity left examined as to its accordance with the graduation in the required place. If by accident too much gas has been thrown out, a little more must be added, and the adjustment proceeded with as before. If the gas be valuable or in minute quantity, then the small bubbles ejected should not be thrown away, but caught in a little tube held over them, and reserved for other experiments. A very quick and accurate adjustment of a required quantity of gas may in this way be obtained.

780. In observing the volume of gas in a tube, after having brought the internal and external surfaces of water to a level, the necessity of lowering the eye to the level of the water may be avoided by closing the mouth of the tube with the finger, and then raising it out of the water to the height of the eye: but the act of closing the tube must be so performed, that the pressure of the finger does not compress the gas within, and raise the level above its proper place. If the finger be applied to all parts of the edge at once, and then pressed hard, this effect will almost certainly take place. To avoid it, the finger should not be applied directly against the mouth of the tube, but a little obliquely, pressing it hard against the part of the edge it first meets, and then folding it over, so as to cover the mouth gradually from one side to the other: the pressure at last upon the whole edge being less than that with which the operation began. In this manner the tube may be closed without any

change of level, and it should be observed during the operation, that this is the case. When the habit is once attained the practice is quick, and in long sets of pneumatic experiments the operator is enabled by it to avoid some degree of fatigue.

781. The barometer and thermometer should be attended to in all these experiments, unless the latter are brief, or are such as to require merely relative portions of two gases, their absolute quantities being unimportant.

782. The operations which have been described have all been illustrated by reference to the water trough, and to gases permanent over it. They are the same in principle as those which will be necessary in experiments at the *mercurial trough* (734), with those gases which, being soluble in water, cannot be preserved over that fluid. The first point the student has to remember at the mercurial trough is, the excessive weight of the fluid with which he is working, and its influence in his operations, either as coinciding with or opposing the pressure of the atmosphere. If the extremity of a retort, or the mouth of an apparatus, delivering gas, be immersed, for example, an inch in the water trough and another to the same depth in a mercurial trough, the pressure upon the interior of the apparatus, which is so little as to be unimportant in the first case, becomes of consequence in the second, being nearly fourteen times greater. The latter, if unattended to, might derange and burst open joints made by soft cement or lute; might force the evolved gases through bladder or junctions quite tight to the pressure of water; and might blow out a tube or retort heated to redness, as in the preparation of oxygen gas from the chlorate of potash, which would have suffered little or no change at the water trough. Hence the beak of such apparatus should be immersed to no greater depth in the mercury than is necessary to insure the safe delivery of the gas into the jar placed to receive it. Hence also the shelf of the trough should not be covered with mercury to a greater depth than is necessary to secure the mouths of vessels placed upon it; and jars, if supported by other means, as by trivets or stands, in small or temporary troughs, should be

so arranged that their mouths may not be too far below the surface whilst receiving gas.

783. The mercurial jars are, as before described (737), to be strong, and ground at the edges. If they are lipped, which is very desirable in many cases for the advantage of transferring, the lip should be level with the rest of the edge, so as to bear upon a flat surface at the same time with the other parts; and not, as is usually the case, retiring outwards towards the bottom of the jar, so as to leave a space between the lip and a glass plate applied to the mouth. The jars may be filled, either by inverting them in the mercury of the trough itself (749), or with mercury from another vessel; in the latter case the mouth is to be closed by a glass plate (1348), the jar afterwards inverted, and its mouth immersed in the metal of the trough, and the plate withdrawn. But when jars containing mercury are thus closed, either for the purpose described, or the transference of gas, a strong hold on the plate must be retained, to prevent its displacement by the weight of metal upon it.

784. In moving a jar partly or entirely filled with mercury, from one part of the trough to another, great care should be taken to prevent its receiving any sudden blow or jerk, for though slight in appearance, it might from the weight of the mass moved, suffice to break the jar; upon such occasions the whole weight of mercury suddenly descends, sometimes deranging every thing in the trough, besides occasioning the loss of the metal and the escape of the gas. The jars are, under these circumstances, most liable to injury by slight blows against each other, or against the iron of the trough, when they take place upon the edges or sides.

785. When a mercurial jar contains gas, it may be removed from the trough, as already mentioned (737, 783), by a glass plate; but if it contain a considerable quantity of mercury, it is safer to effect the transfer by a little evaporating basin (743, 751).

786. When a capped jar is to be filled with mercury, by the assistance of the mouth (754), the jar should be inclined as much as possible, to diminish the height of the column

of air within it, as well as the labour attending the operation; then, by applying the mouth to the stop-cock, and using it to exhaust, in a manner almost the reverse of that described for blow-pipe practice (222, &c.), the air may be withdrawn, and the mercury gradually raised until it fills the jar. Relief should be afforded to the mouth by closing the stop-cock occasionally during the operation; the cloth should generally be applied over the aperture (754), and no moisture should be allowed to enter the stop-cock.

787. The transference of gas from vessel to vessel under mercury, is the same in principle with transference under water, but differs from it in consequence of the opacity and weight of the fluid; the first of which prevents the experimenter from watching the motion of the gas, and obliges him to work in the dark, whilst the second causes the bubbles which leave the decanting jar to be thrown up through the fluid with considerable force. Great care is therefore required in these operations, and especially with tubes. The relative and desired position of the mouths of the vessels must be judged of principally by feeling with the fingers. The depression of the decanting tube should be very slow and gradual. The escape of the first bubble should be watched; if it ascends into the receiving tube, all is well, and the position of the mouths should be steadily retained; but if it escape into the air, the position should be changed. Generally speaking, the mouth of the decanting vessel ought to be farther under the mouth of the receiving vessel than is required in water. When tubes are the vessels employed, the use of the fingers in closing the sides (763) is often highly advantageous.

788. There is one circumstance in which water and mercurial troughs essentially differ, and of which the student should be fully aware, as it will account to him for many accidents that otherwise might occur at the commencement of his experience in the transferring and collecting of gases, and enable him in most cases to avoid them. This consists in the property which water has of wetting and adhering to the surfaces of the jars and apparatus concerned in operations at the pneumatic trough, which is not possessed

by mercury. Hence it is, that portions of gas expelled from apertures under water, rise in distinct bubbles through the fluid about them; for the adhesion of the water to the solid substances generally in use is greater than that existing between its own particles. It is not so, however, with mercury: that metal does not come into such close contact with glass or other substances as to adhere, and hence it often happens that the gas ejected from the aperture, instead of being thrown as a bubble into the fluid metal, suddenly returns round the edge, and passes up in a stream between the vessel and the mercury. It is in this way diffused for a moment in thin films over a large surface, and ultimately escapes at the ring, where the surface of the mercury ought to be in contact with the vessel from which the gas is thrown out. The collection or retention of the gas in such cases is utterly impossible, its passage in the form of *bubbles* being necessary for that purpose.

789. This insidious emission of gas takes place with little or no disturbance of the mercury, and is sometimes quite imperceptible. It can only occur when the vessel delivering the gas proceeds from above downwards, in the manner of a jar, or the beak of a retort, or a descending straight tube; so that when the extremity of a tube is curved, and made to turn up under the surface of the mercury, it is avoided. It is very usual with dirty vessels, and may often be prevented by wiping them clean: this is especially the case with the beaks of retorts delivering gas. It is more likely to occur in dirty than in clean mercury (1278). In such cases, though it may not take place immediately, it frequently will after the lapse of a short time, the agitation of the mercury apparently collecting a film, or diminishing the adhesion between the metal and the glass. Wiping the glass with a clean cloth, even whilst under the metal, is then a remedy.

790. Some gases have a tendency to occasion this effect more than others, and amongst them may be quoted fluoroboric and silicated fluoric acid gases, and euchlorine. The necks of retorts delivering these gases should be wiped occasionally. The effect happens more readily when the sides

of the vessel or delivering tube approach to perpendicularity, than when they are much inclined, so as to approximate a horizontal position; and finally, it often occurs between the fingers and the mercury, the transpired matter on the surface of the skin apparently facilitating the effect. Hence, when the fingers are brought into contact with the gas in transferring operations, they should, when the effect is likely to occur, be bent upwards under the mercury as much as possible.

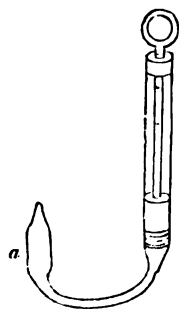
791. It frequently happens that small quantities of gas are to be taken from larger portions, and transferred to other situations. This is constantly the case in analytical and eudiometrical experiments, where small volumes are required in tubes or narrow vessels. Another common case is the transference of a small portion of gas from a jar over water into a vessel over mercury, the transmission of water at the same time being avoided. As these operations are frequent, several useful contrivances have been invented to facilitate them.

792. A common method of transferring a little gas from the water to the mercurial trough in the dry state is, to fill a tube with the gas over water, to close it by the finger, then removing it from the trough, to wipe the outside of the tube and hand dry, taking care that the gas be securely retained during the operation. The tube is afterwards to be carried to the mercurial trough, the finger to be removed, and a little piece of bibulous paper, tightly rolled up, introduced through the mercury into the gas. By re-applying the finger, so as to close the tube, and shaking the piece of paper about within, it imbibes a large portion of the water, and the gas may afterwards be decanted into another tube filled with mercury, without any risk of water passing with it, for the fluid will be retained by the paper or by adhesion to the glass. The gas is thus obtained in a dry state, or at least without the presence of any fluid water. With regard to its hygrometric state, it, of course, still remains saturated with aqueous vapour.

793. A very useful contrivance for the same purpose, due

to Mr. Cavendish, is thus described by Dr. Henry.* "A tube, eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at the end, so as to resemble the italic letter *l*. The point is then immersed in quicksilver, which is drawn into the tube till it is filled by the action of the mouth. Placing the finger over the aperture at the straight end, the tube filled with quicksilver is next conveyed through the water, with the bent end uppermost, into an inverted jar of gas. When the finger is removed, the quicksilver falls from the tube into the trough, or into a cup placed to receive it, and the tube is filled with the gas. The whole of the quicksilver, however, must not be allowed to escape, but a column must be left a few inches long, and kept in its place by the finger. The tube is to be removed from the water, and dried by an assistant with a towel or with blotting-paper; the point of the bent tube is then to be introduced into the aperture of the tube standing over quicksilver, and on withdrawing the finger from that aperture, which is now uppermost, the pressure of the column of quicksilver, added to the weight of the atmosphere, will force the gas from the bent tube into the one standing in the mercurial trough."

794. Mr. Pepys has invented a very useful instrument for the transference of small quantities of gas from one vessel to another over the trough. It is made of a piece of glass tube, about half an inch in diameter, and five inches long, attached to a piece of smaller diameter, which, after bending as in the figure, terminates in a chamber at *a*, which, being cylindrical for the greater part of its length, terminates in a capillary tube and aperture. A small piston, rendered air-tight by tow and tallow, is fitted into the cylindrical tube; it is moved by a rod and ring, the rod passing through a box which closes the upper aperture of the instrument, but which should not be air-tight. A portion of mercury is placed



* Elements of Experimental Chemistry, i. 22.

above the piston, and the space between it and the capillary opening of the chamber is filled with the same metal when the piston is in the position depicted. Upon raising the piston, the mercury follows it, and descends into the chamber *a*, the space left by it being immediately filled with the air or gas which has access to the capillary opening. The rod has a graduation upon it, by which it is known when a tenth of a cubical inch of air has entered the chamber.

795. The following is the mode of using this instrument. Suppose it necessary to transfer a little gas from a jar to a eudiometer tube, both standing over the same trough: the piston is to be depressed until the mercury entirely fills the chamber *a*, even up to the aperture; that end is to be dipped into the mercury in the trough, and passed under the edge of the jar containing the gas; it is then to be raised above the surface of the mercury within, and the piston lifted: this will cause the descent of the mercury in the chamber *a* within the jar, which consequently will be replaced by the gas surrounding it. As soon as enough has entered, the motion of the piston is to be suspended, the aperture of the instrument depressed into the mercury, the piston raised a very little for the purpose of drawing a globe of mercury into the capillary part, the chamber *a* again elevated into the jar to ascertain that this has been done, and then the instrument removed through the mercury away from the jar. The portion of gas within it will be confined both above and below by the metal, and when it is to be transferred to the eudiometer tube, all that is necessary is to introduce the capillary opening into the mouth of the tube, and to depress the piston. The gas is immediately ejected from the chamber, and in a manner so much under command, that it is easy to throw up just that quantity which, by the graduation on the eudiometer tube, or on the stem of the instrument, is known to be required for the experiment. When measuring by the graduation on the instrument itself, it is necessary to bring the level within and without the jar from which the gas is taken to the same height, or else the gas measured will not possess the same volume at common pressure.

796. The same instrument is equally useful in removing portions of gas from a jar over water, and conveying them in a dry state to a jar or tube over mercury. Being full of mercury, it is to be introduced into the jar as before; water rarely adheres in any quantity to the summit of the capillary termination, or if a drop should, a slight lateral shake throws it off. By raising the piston, the mercury in the chamber falls and the gas enters; to confine it there, the instrument should receive a cautious jerk, so as to throw the mercury up towards the capillary opening; it will be found easy to make a globule adhere there, and when that is the case, by depressing the piston, to cause it to enter into the capillary part so as to close it perfectly. The instrument is then to be removed from the jar and water, wiped dry, and the gas conveyed into the required vessel, as before.

797. The instrument described and figured (151), is used by Dr. Hare in transferring accurately measured portions of gas from one vessel to another over mercury. Its use is easy, and will be understood from the description already given of the instrument. When full of mercury, the beak is introduced under the edge of the jar into the gas above, and by withdrawing the rod a certain number of degrees, an equal volume of the gas enters, and is easily transferred to any other vessel at pleasure.

798. The general processes for measuring gas over mercury are the same with those already directed for similar operations over water (767); the propriety of marking the jar or tube, before any attempt to estimate the volume, is even greater here than on the former occasion, because of the greater risk of the gas escaping in transference, or of the occurrence of other accidents. When regulating the quantity in a tube (775), the finger is not of the service in this as in the former case, for the reasons already stated (788, 789); but to make the utmost use possible of it, with the least risk of accidental escape of the gas, it should be held in a bent position under the mercury, rising upwards to the extremity and not *from* it, that the chances of escape of the gas may be diminished (789). It is in cases where

these difficulties with gas over mercury occur, that the instruments just described are particularly useful.

799. When the gas to be measured is in a tube, the advantage of the process (767, 772), in which the height is marked, the gas transferred and thrown away, and its volume ascertained by the weight of mercury replacing it (126, 131), is much greater over the mercurial than over the water trough, simply because it dispenses with the somewhat uncertain operation of transferring the gas under mercury. But the experimenter must then remember the cautions already given, with regard to the opposite convexities of the mercury, when it is at first confining the gas, and afterwards replacing it (135); and besides marking the true bulk with care, he should be equally careful in estimating the quantity of mercury which is to replace it.

800. In all measurements and estimations of gas over mercury, particular attention should be given to bring the metal inside and outside the vessel to the same level; or if there be not sufficient depth of mercury for the purpose, the height of the surface in the jar or tube above that in the trough should be accurately measured and noted down. This becomes a deduction necessary to be made from the observed height of the barometer, when the volume of the gas is to be corrected, and its true bulk at mean temperature and pressure ascertained (883).

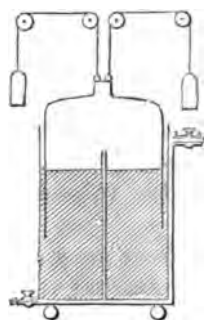
801. In experiments requiring the use of a large jar at the mercurial trough, it is frequently desirable to possess the means of raising or lowering the surface of the mercury in it without moving the jar. Thus, if such a jar were placed over the trough, and it were required to raise the mercury within an inch or two, as in Lavoisier's experiment on the analysis of air, it is easily done by passing one leg of a glass syphon under the mercury into the jar, applying the mouth to the other, and withdrawing air (786). When the mercury is sufficiently raised, the end of the syphon in the mouth is to be closed by the tongue, which must not be removed before the other end has been withdrawn from the jar, through the mercury, by the same way in which it was introduced. Or if, during an experiment,

the gas has been absorbed, and the mercury stands very high in a large jar, so as to require care in letting so heavy a mass down, a syphon may be introduced as before, and air allowed to pass into the jar through it, the mercury falling gradually as the air is allowed to enter. To prevent the mercury entering into the syphon during the transit of its extremity through the metal, that end should be closed by introducing a plug of twisted paper into it, or paper should be wrapped about it; either will be sufficient to keep the metal out, without stopping the passage for the air.

§ 4. *Of larger and independent Vessels, for the retaining and storing of Gas.*

802. Numerous vessels have been contrived for the retention of gas, independently of the use of jars, or of the water or mercurial trough, and it is necessary that the student be acquainted with the principles and uses of many of them. All have their respective conveniences; some consisting in great capacity, others in facility of operation; and others, again, in their security as to the retention of particular gaseous bodies.

803. *Gasometer.* The vessel usually thus designated may be compared to a large jar suspended in a trough, of size just sufficient to allow its entire immersion in an upright position. The gas-vessel, or bell, instead of resting on a fixed support, is suspended by cords or chains passing over pulleys, and having weights at the opposite extremities to counterbalance the vessel. The trough, cistern, or tank, as it is called in large instruments, is nearly filled with water, which remains constant in quantity, the aerial capacity within the gas-vessel being increased or diminished by raising or lowering it in the water; it is thus adapted to the quantity of gas it may contain. The passage of the gas to and from the gasometer is effected along pipes permanently fixed. A single pipe is sufficient in the simplest form of instrument, and this commencing at any convenient place on the exterior of the tank, is conducted through its bottom, and made to rise so high within, that its extremity shall be above the surface of the water. By connecting the



external aperture with proper apparatus, gas may be made to pass from it into the gasometer, or from the gasometer into the apparatus. The accompanying woodcut, presenting a section of this instrument, will illustrate its principle, and assist the comprehension of the annexed directions for its use. The actual construction of the instrument, and its numerous variations in form and adjustments, make no part of our subject.

Gasometers were formerly much more used in the laboratory than at present, and great care was paid to their construction, for the purpose of obtaining an uniform pressure. They may be made of a great variety of materials. They have of late years been constructed of enormous size in coal gas works, and beautifully arranged with regard to their system of pipes.

804. There is nothing difficult or particular in the use of a gasometer. The water in the tank should never rise so high as to endanger its running into the passage pipe, it being necessary that this should be preserved perfectly free. If water should perchance get into the pipe, it may be drawn out at the lower stop-cock. The gas-vessel should be of such depth as to sink entirely into the water when required, and is advantageously contracted above into a small chamber, intended to receive the end of the pipe, and thus to allow of the expulsion of nearly all the air except the small portion the pipes may contain. When it is to be filled with gas, the cocks should be opened, the bell depressed, until it be as empty of air as possible; one of the cocks is to be shut, and the other connected by a tight joint, with the apparatus delivering gas. This may be a retort, or a bladder, or a funnel placed in the water trough, or in any other vessel. When the operation is over, or the gasometer sufficiently full, the stop-cock is to be closed, and the junction to be disunited.

805. When the gas within the gasometer is required for use, it may be taken out at that stop-cock which is most con-

venient. If it be desired to fill a bladder, it should be attached to the end of the stop-cock; or if a jar over the pneumatic trough is to be filled, a piece of tube should replace the bladder, and its open extremity pass into the water of the trough under the jar (746); or if it be required to pass a stream of the gas through a blow-pipe (252), the blow-pipe should be attached to the end of the tube just mentioned.

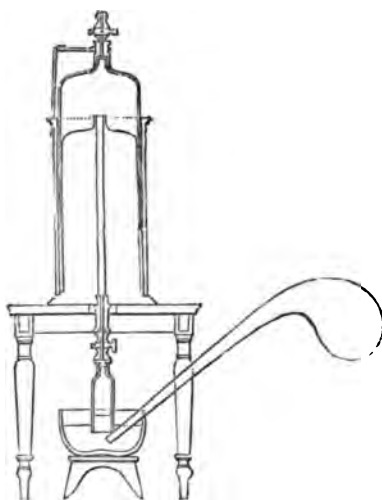
806. The entrance or exit of gas to and from the gasometer, is governed principally by the pressure exerted upon the contents of the vessel; this being again dependant upon the pressure exerted by or through the bell itself. If the hand press upon the bell it presses also upon its contents; in consequence of which the water on the outside rises to a higher level than that inside, and the gas tends to issue by any open channel, and with a force proportionate to the pressure. On the contrary, if the bell be forcibly raised by the hand, the previous pressure is diminished, and to such an extent as to make it less than that of the atmosphere on the exterior; the level of the water without falls, and becomes lower than that within, and if any passage be open, the air will enter into the gasometer, being forced inwards by the superior external pressure.

807. These variations and arrangements of the pressure on the contents of a gasometer are very important, but in practice they are effected by the addition of weights either to the bell or to its counterpoise, or the inverse subtraction of them, which has the same effect. Any arrangement of weights which makes the bell preponderate, increases the pressure in proportion to that preponderance; the reverse arrangement diminishes the pressure. Now, on receiving gas into the instrument, care should be taken that the preponderance of the bell should be no more than what is easily overcome by the effort of the gas to pass in, and it may sometimes be almost entirely removed with advantage. On the contrary, when the gas in the vessel is to be used, a pressure outwards is required, more or less, according to the force which opposes the transfer; thus, but little pressure will enable it to pass from the gasometer into the air, or

into a bladder in the air, though more will be necessary, when it has to be thrown out through an aperture at the depth of two or three inches or a foot under water.

808. When a gasometer is received from the instrument-maker, it should in the first place be examined as to tightness. This is done by putting water into the cistern, then half filling the bell with air, closing the apertures, loading the bell considerably so to occasion much pressure outwards, and leaving it so for some hours. If at the end of that time the bell has not sunk below its first position, it indicates the tightness of the instrument.

809. A mercurial gasometer is the same in principle as those already described, but in order to avoid the weight and expense which would arise from filling the cistern with mercury, its interior is principally occupied by a core, allowing space enough between it and the sides of the cistern for the jar, and for mercury to make it tight. To Mr. Pepys* we are indebted for an excellent instrument of this sort, made of iron, and having a very convenient arrangement for the introduction of gases from retorts. This has been connected by Mr. Newman with his large mercurial trough.†



The accompanying sectional diagram will illustrate the arrangement by which the gasometer is charged: the iron core and the sides of the cistern may be distinguished, and the jar is seen half full of gas, and closed by a stop-cock above. The core is traversed by a perpendicular passage consisting of a glass tube cemented into its place, which being open above into the bell of the gasometer, terminates beneath

* Phil. Mag., v. 154.

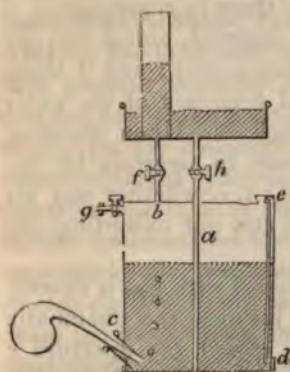
† Quar. Jour. of Science, i. 185.

in a stop-cock. To this a small funnel is attached by a screw cap cemented upon it; and beneath the funnel is placed a glass cup or dish containing mercury, and raised so high as to cover the edge of the funnel, about the third or fourth of an inch in depth. It, in fact, is a small mercurial trough, by means of which the gas from the retort is made to pass into the funnel, and from thence through the core into the jar above. On commencing operations after the gasometer has been filled with mercury, the jar found to be in order, the stop-cocks clean and moveable, and the trough beneath arranged, the first step is to open both stop-cocks, and to depress the jar in the mercury until all the air is excluded, then closing the upper cock to leave the jar to itself. The buoyancy of the glass in the mercury will cause a tendency to rise, and cause also the ascent of the mercury a little way in the funnel beneath, above the surface of that in the dish. If, after leaving it an hour or two in this state, it be found that the jar has not risen higher than at first, the tightness of the instrument is ascertained. The beak of the retort, or the end of the tube delivering gas, is then to be passed beneath the edge of the funnel, the gas allowed to enter the latter, and the jar will be seen to rise at every bubble. When as much as is equal to the contents of the funnel, and the tube of the gasometer has entered, the upper cock is to be opened, and the jar depressed, its contents thrown out, the cock shut, and the gas collected as before. This is to be done once or twice more, to insure the rejection of all common air, and then the future portions of gas are to be collected and preserved for use. When the gasometer is full, the retort is to be removed, the lower stop-cock shut, the temporary trough taken away, and the included gas reserved until required. When wanted, it is to be drawn off from the upper stop-cock, the apparatus being connected with it in the usual manner.

810. The gasometer has been to a great extent superseded by another instrument, also the invention of Mr. Pepys,* which can hardly be dispensed with in the laboratory. It has been called a *gas-holder*, and is a valuable

* Phil. Mag., xiii. 153.

vessel for the retention of a stock of oxygen or any other



gas which is in constant requisition. It is usually made of japanned copper, and consists of a close cylindrical vessel, surmounted by a circular trough of the same diameter, but comparatively of small depth; a pipe *a*, proceeds from the bottom of the trough, and passing through the top of the air-chamber, descends until near the bottom, where it terminates in an open extremity. A second pipe, *b*, also passes downwards from the trough, but merely enters into the top of the air-chamber. Both these are closed by stop-cocks, *f*, *h*, placed between the trough and the chamber. A stop-cock, *g*, is also inserted into the top of the air-chamber on one side, and finally a short piece of wide pipe, *c*, enters through the side of the air-chamber near the bottom, and is placed obliquely, so that the highest part of the edge of the inner aperture shall be lower than the lowest part of the edge of the outer aperture, by at least half or three-quarters of an inch. It is closed and made air-tight occasionally by a plug which screws into the aperture. A glass tube is cemented into two sockets at *d* and *e*, which opening into the air-chamber, render the tube in fact a part of that cavity; its use is to indicate the quantity of water, and consequently the quantity of gas, within. All the joints and seams should be perfectly air-tight; this point may be ascertained in the following manner. The aperture *c* being closed by its proper plug, the three cocks above are to be opened, and water poured into the trough and allowed to descend into the air-chamber until it is full; the vessel is then to be inclined a little, the lateral stop-cock being raised upwards, so that the air may escape by it until water only issue. This and the other stop-cocks are then to be closed, and the guage observed to ascertain whether the vessel be full of water, or if a bubble of air be at the top, to mark the place

where it stands. The plug at *c* is then to be unscrewed and removed. The water cannot escape there in consequence of the manner in which the pipe *c* is inserted, unless the air finds access inwards above at the same time; and if there should be any leak, the weight and tendency of the water to descend will draw the air through it. Upon standing therefore a few hours, it will be easy to ascertain by the guage whether the vessel be tight; *i. e.* whether any air has gained access, or any water has run out excepting the first small portion.

811. The process of filling this vessel with gas is exactly the same in principle as filling a jar over the pneumatic trough. The stop-cocks are to be closed, the aperture *c* opened, and the beak of the retort or the tube delivering gas is to be introduced at *c*; the gas will bubble up through the water and displace the fluid. Provision, however, is to be made to convey away the water. For this purpose the gas-holder may be filled near the sink, and the water allowed to run out; or if it has to be brought towards the furnace, as in the making of oxygen gas, it may be mounted on a stool, and the water received into a pail placed beneath the opening. In such cases it will be found useful to hang a piece of wet tow about the tube conducting the gas, so as to be in contact with the edge *c*; this will lead the water into the pail (468).

812. The descent of the water, and therefore the quantity of gas introduced, is indicated by the guage. When the gas bubbles out at *c*, the vessel can retain no more; the tube or retort is to be withdrawn, the plug screwed up tight, and in that state the gas is securely confined, and may be preserved for many months, provided water is retained in the trough above.

813. No difficulty occurs in transferring the gas from this vessel into any other that may be required. The lower aperture is, in these cases, of no use, and is to be kept closely shut. Upon opening the stop-cock of the pipe *a*, the water will flow down it to the bottom of the air-chamber until such time as, having accumulated there, the gas above is compressed by a force equal to the weight of the column

of water in the tube and trough. No more water will then descend unless the stop-cock *f* or *g* be opened, when the gas will immediately rush out, urged on by the column of water in the tube, and the water above will supply its place. The process, therefore, of filling a jar or a bladder, or passing the gas through a tube, is very simple. In transferring it to a jar, for instance, the latter must be first filled with water, inverted (751) in the water of the trough, and placed over the aperture of the pipe *b*; then having opened *h* as before described for the purpose of causing pressure on the gas within, the stop-cock *f* is to be carefully opened, when the gas will rush up and quickly fill the jar. The water from the jar descends into the trough to supply the place of that which passes into the air-chamber. The cock *f* is to be closed as soon as enough gas has passed out, when *h* is to be shut, the jar of gas transferred and used as may be required. Or suppose that a bladder is to be filled with gas: the common air is first to be thrown out, the bladder attached to the cock *g*, pressure is to be given by opening *h*, then *g* is to be cautiously opened, and the bladder to be filled; the water which is necessary being supplied to the trough above from a jug or pail; finally, the cocks *g* and *h* are to be shut, and the bladder removed.

814. It is sometimes necessary to introduce gas from a bladder *into* the gas-holder. In that case the full bladder is to be attached to the cock *g*, all the cocks being closed; the plug at *c* is to be opened, and then the cock at *g* cautiously turned to allow the gas to pass in, the water at the same time passing out; the cock is then to be closed, and finally the plug *c*.

815. If the transfer of gas is to be effected through a tube, as, for instance, in arranging the oxygen blow-pipe (252), or supplying inflammable air to a jet, the pipe must be attached to the cock *g*; the pressure of water given as before, and the emission of gas regulated by the extent to which the stop-cock *g* is opened.

816. The inventor has provided even for occasions on which a greater pressure than that of two feet of water may be required, by associating a long tube and funnel with the

instrument. This being screwed into the mouth of the pipe *a*, where it enters the trough above, and retained full of water, subjects the gas in the instrument to the pressure of a column four feet in height, and is occasionally very useful.

817. It requires no particular skill to make one of these air-holders out of a good cask by the addition of a few tubes, cocks, and a funnel : but it must always be retained moist.

818. It is essentially necessary that in all the transfers of gas *from* the instrument, an abundance of water be retained in the trough above, to supply the place of that which passes into the air-chamber. It is also necessary to be aware of the possible introduction of common air with the water, even when there is considerable depth in the trough. When the gas is passing rapidly out at the lateral stop-cock, and consequently the water rapidly descending through the tube, it will, if unattended to, frequently acquire a rotary motion, which, from mechanical causes easily explained, will at last produce an aperture commencing at the surface of the water and descending to the very bottom of the tube. Down this air is rapidly carried by the descending water, which, mixing with the gas in the instrument, deteriorates it, and with inflammable gases may lead to dangerous results. Hence this rotary motion, when observed, should be disturbed. The formation of the central channel for air may easily be prevented by allowing a large bung or a piece of light wood to swim on the surface of the water. If rotation does take place, it will draw the floating mass to the centre, and prevent the air from passing down by hindering the formation of a channel, if water be plentifully supplied.

819. When gas-holders are to be left for several weeks or longer with gas in them, it is advantageous to put a board or large earthenware plate over the water in the cistern or upper part. It prevents the evaporation of the fluid too rapidly, and retains all in order.

820. Amongst vessels for the retention of gas may be classed *bladders* and *bags* ; they are very useful in many receiving or transferring operations, or when subjected to pressure, in supplying a constant stream of gas for a length

of time. *Bladders* of different sizes are required. The necks should be softened by water, opened, drawn over the lower part of a cap similar to a retort cap (832), and tightly tied with twine. A stop-cock screwed into the cap renders the vessel complete. If the bladders are used in a dry state, the mechanical action to which the membrane is subjected during expansion and contraction, and otherwise, soon breaks the substance, and they become useless. To prevent this, and also to remove their rigidity, which is inconvenient, bladders are commonly moistened before being used. This renders them very conveniently flexible for present purposes, but they become more and more rigid each time they are wetted and dried, and soon break into holes. A bladder may be made to continue tight for a considerable period by pouring a little oil into it at first, and allowing it to become saturated. It is not, then, to be wetted for use, and is at no time so pleasant to work with as a wet bladder. Bladders should be kept in a moderately expanded state, not tightly blown, nor on the contrary compressed together; and this is more particularly necessary with those bladders which are wetted each time they are used, and are laid aside in a moistened state. Bladders are not perfectly tight to gases, and are less so when dry than when moist; consequently gases should not be retained long in them, and never longer than is absolutely necessary. Hydrogen passes through them more rapidly than any other gas.

821. *Gas-bags* are of different kinds. Some are now made of layers of gold beater's skin or animal membrane, laid one over the other until of sufficient thickness: these may be constructed of any size or shape, do not require wetting, are more flexible than dry bladders, and less pervious to gas; when injured they are easily mended by the application of moistened membrane. Others are made of two layers of woven material, having between them a layer of caoutchouc or India rubber, which serves to bind the whole into one impervious substance; and when the substance has been prepared for this purpose with a thick coat of that peculiar body, may be made permanently air-tight. It is, however, to be understood, that the fabrics sold as

waterproof, and stated to be made so by caoutchouc, are not sufficiently air-tight for these applications. These bladders and bags are useful in transferring gases from vessel to vessel, as between jars and air-holders; and when filled and covered with a weighted board, they will supply a constant stream of gas for a length of time.

822. *Caoutchouc or India rubber bottles* are useful vessels in particular circumstances, and may be had at the instrument-makers; their uniform expansion in all directions having been previously ascertained. It is necessary to introduce the gas by a condensing syringe, in consequence of the force required to dilate the bottle; but being introduced, the spontaneous contraction of the caoutchouc upon it is very useful in forcing it out through the stop-cock, and hence the particular uses of these bottles. A bottle, at first not more than three inches in diameter, may be extended till it contains half a cubic foot of gas or more, and upon allowing its contents to escape, will contract to nearly its original size.

823. Those who endeavour to prepare these bottles for themselves, will not succeed with more than one in four or five. They should be selected of uniform thickness, and without external marks or depressions; those which are lightest in colour are generally best. They should be heated in hot water, or in steam, for an hour or two, and then rolled between the hands until they become perfectly flexible; when cold they should be tied upon caps, having a stop-cock and a syringe attached; the air is then to be gradually thrown in. The bottle, when fully distended, generally becomes thin at one place first; if upon expansion by air this thinness extends to the neighbouring parts, all is well; but if it increase rapidly and partially, there is little chance of the bottle being made useful. The air should be introduced in successive portions, a lapse of time being allowed after every few strokes of the piston, especially during the first expansion. Caoutchouc bottles, thus fully expanded and rendered thin, should not be exposed to heat on one side only or partially, for the heat, diminishing the cohesive attraction, allows the neighbouring parts to con-

tract by distending the heated part, which, becoming gradually thinner, at last burst into a hole.

824. Finally, *glass bottles* are frequently of great service in the retention and preservation of gases, and more especially of chlorine gas, which cannot be retained for any length of time over water, in which it dissolves, or over mercury, on which it acts. The bottles should be wide-mouthed and accurately stoppered (433), their capacities being from four or six ounces to a quart. The necks and the stoppers should in the first place be wiped dry, a little tallow or lard applied to the stopper, and the latter moved round in its situation, so as to disperse the tallow over the ground surfaces, and render the stopper easy in its motion and at the same time air-tight. The bottles should then be filled with gas as if they were jars (749), the stoppers put in under water, and pressed into their places, and then the bottles be stored away in a dark place of nearly uniform temperature, in an inverted position, and with the stopper and neck immersed in water. This may be done by providing earthenware jellypots, or similar vessels, one for each bottle. When water is put into these, and the bottles inverted in them, the gas is rendered perfectly secure, and may be preserved for months, and even years. These receiving vessels may be conveniently made out of fractured wine bottles, when they remain sound towards the bottom, the upper part being cut off by a hot iron or otherwise (1213).

825. Dry bottles may be filled with such gases as, being either much heavier or lighter than atmospheric air, are at the same time soluble in water, and cannot be collected over that fluid. For light gases, such as ammonia, the bottle to be filled is to have its stopper greased, and is then to be placed in a vertical position, with the mouth downwards over the end of the tube or retort neck delivering the gas, which at the same time is to be directed upwards, until it touches the bottom of the bottle; the light gas occupies the upper part of the vessel at first, and gradually displaces the air: ultimately, from the addition of fresh portions above, it flows out at the mouth of the bottle, and when by

applying a slip of moistened turmeric paper to the aperture, it is judged from the change produced that the gas in the bottle is nearly or quite pure, the tube or retort is to be gradually withdrawn, with as little disturbance of the gas within as possible, and the stopper instantly put into its place.

826. Many gases, such as muriatic, sulphurous, or carbonic acid gas, are on the contrary conducted downwards to the bottoms of bottles placed with their mouths upwards, which when they freely overflow with gas at the mouths, are to be withdrawn and quickly stopped. The overflowing of the muriatic acid gas is known by the fumes which seem to issue from the mouth of the bottle. The fullness of vessels receiving sulphurous or carbonic acid gases may be ascertained by bringing a lighted taper carefully near the mouth, the rapidity and appearance of its extinction being a sufficient indication. In all these cases it is necessary to allow an excess of gas to pass through the bottles, and to continue the introduction of fresh gas even after the bottle is supposed to be full, a portion being willingly thrown away to ensure the greater purity of that which is retained. The gases above mentioned may readily be collected, especially in small bottles, intermixed with not more than between a fiftieth and a hundredth part of common air.

§ 5. *Connexion and Communication*

827. Having already had occasion to mention caps and stop-cocks, it will be necessary more particularly to consider the general uses and arrangement of these and other pieces of apparatus, intended to facilitate the connexion or disjunction of different instruments, or the different parts of a complicated arrangement. Laboratory stop-cocks are usually made of brass, and are terminated by a male screw at each end rising from a flat shoulder, so that the intervention of a washer, or collar of leather (830) renders them, when screwed up into their proper apertures, perfectly airtight. The plug of the cock should be very accurately ground into its socket, that no air may pass it. It is

usually held in its place by a collar and screw, so that the experimenter can take it out, examine it, and apply a little wax or fat, whenever there may be occasion. The passage through the cock should not be more than one-eighth of an inch in diameter, and is even advantageously smaller where it passes through the plug, for then its section upon the plug and socket is diminished, and the tightness and security of the cock increased.

828. These stop-cocks are necessarily subject to injury during use, many gases, as chlorine, ammonia, &c., having powerful action upon the metal: they should be frequently looked at, examined, and the plug lubricated (827, 433). It is often necessary to cleanse the air-way, and remove such obstructing matter as has either collected or been formed there. This may be done with a stiff wire; but particular care should be taken, in such operations, that the plug itself, or its socket, be not scratched, or the apertures formed by the air-way upon their surfaces injured, which would soon destroy the tightness of the instrument, and render it useless. The plug when turned round in its socket should move easily and steadily, allow of no shake in any direction, and not permit air to pass. For this purpose, even when new, a little wax or grease should be applied. Tallow is the substance usually resorted to, but a mixture of two parts yellow wax and one part sweet oil is much better, since it preserves the tightness of a stop-cock that is slightly injured, longer than tallow or pomatum. The plug and socket of a foul stop-cock should be cleaned with a cloth, and not with a hard instrument.

829. If the plug adhere, as though, from chemical action or otherwise, it had become so fixed as to be almost immovable, its screw and collar are to be removed, and by tapping the end with wood (not with metal) attempts are to be made to drive it out of its place. If it resist this, and also some degree of force applied to turn it, a little oil is to be dropped in at each end of the stop-cock, and also applied to the end of the plug, and then the whole should be warmed and left for an hour or two, when it may generally be moved. The plug of an old stop-cock commonly re-

quires more wax or tallow than a new one; this should not be allowed to accumulate in the air-way, where it is of no use, but a little piece being put upon each side of the clean dry plug, the latter is to be introduced into the socket, equally clean and dry, and then turned round a few times to effect its equal and proper distribution. When chlorine or ammonia has passed through the stop-cocks, the sooner they are looked at and aired or washed as occasion may require, the better.

830. *Washers* or *collars* are round pieces of soft substances, as leather or paper, which, having holes in the middle, are passed over the male screws of the stop-cocks, so that when the latter are connected with other apparatus, the washers are between their shoulders and the sides of the aperture into which the cocks are screwed, and make the joints impervious. They are usually punched out of thin boot or shoe leather, and the pieces being soaked in oil for a day or two, and then cleaned, are ready for use. It is better for many purposes to use wax instead of oil on these occasions. Yellow wax should be melted, and the washers put into it for five minutes; when taken out, they are to be allowed to drain a moment or two, and suffered to cool. When required for use, they should be rendered flexible by the warmth of the hand, before they are put into their places. Such collars will occasionally remain tight for hours together at a pressure of from ten to thirty atmospheres, when an oiled washer would inevitably have leaked; and they are more secure and constant even at common pressures.

831. When the joint has to bear a temperature near to or above 212° , one or more thicknesses of card answer the purpose of a collar better than leather. Sheet caoutchouc (449) may be formed into excellent collars for particular occasions, but it is necessary to be cautious in screwing up the joint. Caoutchouc, from its elasticity, becomes readily adapted to the surfaces immediately upon contact, so that but little pressure renders the joint perfectly tight. On the contrary, were the cock tightly screwed up, the force would be sufficient to press out nearly all the caoutchouc at the edges of the joint; this, although it would not destroy the tightness

of the arrangement, would be of no use, and would injure the collar and spoil it for future service. All dirt should be removed from the surface of the shoulders before the collars are put on, or otherwise it will occasion irregular pressure, and interfere with the tightness of the joint.

832. *Retort caps* are cylinders of thin brass plate, contracted at one extremity by the insertion of a thick ring, in which a female screw is cut, and turned flat at the end so as to screw up tightly against the shoulder of the stop-cock. These caps are of various diameters to fit tubes and necks of retorts of different sizes. The flat extremity at the head of the cap, which screws up against the shoulder of the stop-cock, should have two or three concentric grooves (merely deep lines) turned in it, which will render its bearing against the collar more air-tight and secure. These lines or grooves should be kept free from dirt, by having a point run along them occasionally, and the worm of the screw should also be preserved clean and free from obstructing matter.

833. Caps are fastened upon the ends of tubes or retorts with a particular cement (1123), in the following manner. One is to be selected of such size as to admit the tube and allow a space for cement about the thickness of a card, or a little more, but the cap should never be so small as itself to gripe the glass, or any larger than is necessary to allow room for cement to surround the glass. The cement should be heated to fluidity on the sand-bath, but not to a greater degree; the cap should be warmed over a candle or lamp until it is hot enough to melt cement, and then that part of its interior which is intended to come against the glass, namely, the sides of the cylinder, should be covered with the hot cement, applied by a piece of stick. The cap being then laid on its side by the sand-bath to keep it from cooling, the dry end of the tube or retort is next to be warmed, and a coat of cement applied on the exterior, over every part which is to come into juxta-position with the cap, but the other parts are not to be unnecessarily soiled; so much cement is to be left adhering to the glass, that with what there is in the cap, there may be an excess above the quantity that can be re-

tained between the glass and metal when the two are fitted together. When the cap, glass, and cement, are all so warm that the latter is fluid, or very soft, the cap is to be placed upon the tube, thrust into its right position, receiving a little rotatory motion at the same time, to distribute the cement equally over all parts, and is afterwards to be set aside to cool. When this is well performed, the retort neck, or tube, should pass along until it be stopped by the inside of the shoulder; no cement should soil its interior, or project within the cap, but it should fill every part between the glass and cap, to make a firm, tight junction, and project in a ring from the edge of the cap over the exterior of the glass. The superabundance is easily removed by a knife, and the annular surface left made smooth and tight by a hot wire passed rapidly over it. If a piece of cement, pushed on by the edge of the glass, project in the inside of the cap, it should, when nearly cold, be cut off by a knife, and removed, so that no loose fragment may remain in the retort or tube.

834. When there is a deficiency of apparatus, and caps are wanting, their place may be supplied for the time by corks. Thus, if there be no cap large enough for the aperture of a jar or tube, a very good cork may be selected, made to fit tightly into the aperture, a hole pierced through it, and the cock screwed into this hole; care being taken that the cork be not divided or torn to pieces by the force applied. This may be done so as to be quite tight, or if a small leak occur, a little soft cement (1125) will make all secure.

835. Connecters are short perforated pieces of metal, traversed by a female screw, and terminated by flat surfaces at the ends, so as to screw tightly against the shoulders of stop-cocks (827). They have on their extreme surfaces concentric grooves, like those on the ends of retort caps (832), to meet and hold against the collars. Their use is to connect together stop-cocks, or other parts of apparatus terminated by male screws, and hence their name. They are best made square on the exterior, being then more firmly held in the hand, or by a key, when tightly screwed.

The clean state of the worm, of the screw, and of the grooves, should be attended to (832). The want of these connectors may at times be supplied by a sound perforated cork (834, 1331).

836. The screws of all these stop-cocks, caps, and connectors, should be cut with the same thread, so as readily to fit each other; several of each should be ready for use, and preserved in a drawer appropriated to the purpose (25); those which are old or leaky are to be repaired or rejected, and the rest kept clean and in good order.

837. The tightness of stop-cocks, as well as that of their junctions with connectors and caps, and also of caps, when cemented upon retorts, may be determined in several ways. If, for instance, it be required to ascertain whether a stop-cock is tight, it may be screwed to the plate of an air pump, and the pump worked until the gauge indicates considerable exhaustion. If, without further working of the pump, this indication continue unaltered for some time, it is a proof that the stop-cock is tight. Or the cock may be screwed into the top of a capped jar (740) standing in the water trough, the water raised in the jar to near the top, its situation marked whilst the jar stands on the shelf, and then again after several hours: if it remain unchanged the cock is tight. Or a still simpler method, and on the whole a very good one, is, to close the cock, to apply one end to the mouth, to exhaust the air within the small cavity as much as possible by the mouth, and closing the aperture by the lip or tongue, to allow it to be forced against the cock by the pressure of the atmosphere. If, after a few minutes, the adhesion remains sensibly undiminished, it is a proof that the stop-cock is sufficiently tight to resist the passage of air under considerable pressure.

838. If it be required to ascertain whether a cap has been fixed upon a retort, so as to be quite air-tight, all that is necessary is to screw in a stop-cock before ascertained to be secure, to attach this to the air-pump, and then to exhaust; if the gauge remain for some time as high as it was raised by the exhaustion, all is tight, or if it fall, air finds admission. The same trial may be made, though not so

rigorously, by attaching the retort and stop-cock to a transfer or capped jar, nearly filled with water, and standing on the shelf of the pneumatic trough, and then opening the communication. The level of the water, after the first depression, should be marked, and if it fall not soon afterwards, it is a proof of tightness under pressures equal to that of the column of water in the jar.

839. The apertures of tubes are frequently made to communicate with other apertures very advantageously by connectors of caoutchouc, the formation and application of which have already been described (449). When of a conical shape, they connect apertures of different dimensions, conferring great flexibility and security upon the apparatus (843).

840. Tubes for the conduction of gas and vapour, though frequently formed of rigid materials, as glass, metal, or porcelain (699, &c.), are also sometimes advantageously constructed of flexible substances. Tubes of caoutchouc, three or four feet or more in length, are easily made from sheet caoutchouc, in the manner already described (449), small tubes of six or eight inches long being joined at the extremities, by surfaces freshly cut with a clean sharp knife. Flexible air-tight tubes of any length are now made of canvas and other fabrics, imbued with caoutchouc in the liquid state, or with oil boiled with litharge, &c.

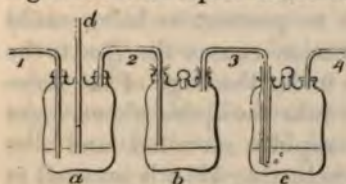
841. It may be useful for the student to know, that very excellent tubes may be formed of pasted paper, sufficiently tight to be serviceable on an emergency in numerous experiments upon large quantities of aëriform substances, such as coal-gas, fire damp, carbonic acid, &c. They should be made by rolling three or four thicknesses of paper round a glass tube, a rod, or a wire, one half of the paper being pasted so as to cause at least the two outer folds to adhere throughout. If after they are made they be brushed over with oil, or being first warmed, with melted wax, they become very tight. A tube very nearly tight enough to hold gas under small pressures may be made simply by rolling up smooth writing paper, and tying it round with thread. When such a tube is wanted for the conveyance of fluids,

the paper may be first oiled or waxed, and then rolled into form (1337).

842. When tubes are used for the ready and rapid conveyance of gas, it is desirable that they should be of sufficiently large dimensions. No difficulty occurs in the usual course of laboratory experiments, but in the arts, and sometimes in large experiments upon the transmission of gas, air, or steam, much annoyance has risen from the contracted dimensions of the tubes employed.

843. In numerous cases of solution or chemical action exerted upon or by gases, there is occasion to pass the gas over successive portions of other substances, and these, when liquid, are best placed for this purpose in an arrangement of vessels first devised by Glauber, but which with some modifications, has since received the name of Woulfe's apparatus (475, 959).

844. In the general arrangement, a series of close vessels are placed side by side, connected by tubes, which originating from the top of those which precede in the series, descend



to the bottom of such as succeed, as in the delineated bottles *a*, *b*, *c*, and the tubes 1, 2, 3. The gas is supposed to be delivered into the bottle *a*, by the tube 1. After having acted upon the water or solution there, it passes out by the tube 2, into the bottle *b*, and from thence by the third tube to the bottle *c*. Now it is necessary in this arrangement that the junctions of the tubes with the bottles be air-tight, or the pressure exerted upon the gas by the fluid through which it is to pass will cause it to escape. These junctions are made in various ways. The tubes may sometimes pass through corks, and be tied round with bladder, or be luted (465, 475, 1100, &c.), as has already been described; or the joints may be ground air-tight, another mode of effecting a junction, which has been noticed (475). But these and similar junctions give a stiffness and rigidity to the whole apparatus, which in consequence of the comparative slenderness of the tubes, and

the size and weight of the parts connected by them, involves considerable risk of fracture to the former, or at least of derangement at the joints by very slight shaking or motion given to the latter. Hence it is desirable to have flexible or moveable junctions, and this is well effected by the use of such caoutchouc tubes or collars, as they may be called, as, being of a conical form, may be tied at the upper edge round the centre tube, and at the lower round the tubulature (451), as is represented at the tubes 2 and 3, bottle *b*. These may be used with most gases, chlorine being perhaps the only one likely to be passed through a Woulfe's apparatus that will act upon them.

845. Another very excellent though more expensive mode of forming a moveable junction, is represented by tube 3, bottle *c*. A wide tube is selected and fixed air-tight, either by grinding or otherwise, into the tubulature; it descends nearly to the bottom, and is cut off obliquely, so as to present an oblique aperture. The connecting tube 3, is made to pass down this tube, and having its end turned a little on one side, though not enough to prevent its being easily drawn up and down, that inclination causes the gas to be thrown off laterally, and to pass under the edge of the large tube, and through the solution, into the space above. An arrangement of this kind is rapidly mounted and dismounted; for the instant the conducting tube is inserted in its place, it is air-tight. It is necessary, in all such arrangements, that the fluid in the bottle (*c*) should rise above the aperture of the wide tube, and that the extremity of the conducting tube should descend below it.

846. Considering the joints as being properly made in any of these methods, let us illustrate the uses of the arrangement by supposing muriatic acid gas to be thrown into the apparatus by tube 1; it will pass into the water, and be immediately dissolved; but as from the continual additions of fresh gas the liquid becomes saturated, a part of the gas will pass into the upper part of the bottle, and propelling the air before it, will enter the bottle *b* by tube 2. Here it will operate exactly as in the first bottle *a*, if the arrangement be the same and the gas be conducted into the fluid:

but if, as in the figure, this be not the case, it will, after acting upon and saturating the fluid as much as practicable by the surface, pass on in a similar manner to the third bottle, and from that to wherever the fourth tube may lead.

847. Such is the simple operation; but it is liable to frequent variations, which are to be met by particular contrivances. Amongst the most essential of these is the application of safety-tubes, intended to admit air when, from any cause, the pressure within is so far diminished as to be considerably less than that of the atmosphere. Suppose for instance that the currents of gas into the bottles *a* and *b* were stopped while solution was still going on: as the water dissolved the gas above it, the atmospheric pressure would force the fluid from the bottle *c* up the third tube into the bottle *b*, and if it reached the aperture of the second tube, even in part into the bottle *a*. If the operation had occasioned the evolution of heat, a mere depression of temperature within the bottle might produce the same effect, and in this manner cause great derangement of the liquid and the failure of the experiment.

848. All this may be avoided by the use of the small safety-tube *d*, first applied by M. Lavoisier from an idea suggested by M. Hassenfratz.* It passes through a tight joint into the bottle, and has its lower extremity immersed in the liquid to the depth of half an inch or more. When the absorption before described takes place, air passes down the tube, enters the bottle, and prevents the recession of the liquid from the other bottles. No air can at any time escape there, but any pressure exerted from within outward is indicated, and even measured, by the elevation of a column of fluid in the tube: in this way such tubes are highly useful in shewing the state of things within. Another tube of safety, called Welter's, has been already described (478), which, being fixed into the middle tubulature of the bottle, will render that just mentioned needless.

849. When the bottles are connected in the manner described (845, tube 3, bottle *c*), by a fixed large tube, the latter becomes a tube of safety, permitting the entrance of

* *Traité Elementaire de Chimie*, 453.

air whenever the external pressure is much above that within.

850. On first setting an apparatus of this kind to work, the student should be attentive to the quantity of water in the bottles, and the depth to which the extremities of the connecting tubes are immersed. Supposing the immersion to be two inches in each of the bottles *a* and *c*, it makes a pressure of four inches, which has to be overcome by the gas passing into the apparatus through the first tube. From inattention, this pressure may be very considerably increased, and to such an extent as to interfere with the arrangement of the apparatus in which the gas is evolved; in consequence of which, lutings may be deranged, and even the vessels burst. Hence as a general rule, the conducting tubes are not to be immersed more than is needful.

851. Upon numerous occasions it is not necessary to immerse the tubes at all, especially in the large way; consequently apparatus may then be used for the liberation of the gas, which would be quite inadmissible were any pressure to be exerted within it. This is particularly the case with muriatic acid, for the solution formed by that gas in water being heavier than either the water or weaker solution beneath it, falls to the bottom. Hence in a muriatic acid gas arrangement, the delivering tube may terminate above the surface of the water as in bottle *b*; the water, as it dissolves the gas, will descend, and this change of place will go on until it be fully saturated. On the contrary, with ammonia the reverse is the case, the solution of that substance being lighter than water; it is essential therefore that this gas be delivered at the bottom of the bottle, that it may always come first into contact with the weakest portions of solution.

852. In several cases the gas is conducted to the bottom of the fluid, that the bubbles in their ascent may cause agitation, and thus favour the solution. This is necessary in dissolving chlorine in water, and is advantageous with ammoniacal and sulphurous acid gases.

853. Although three bottles are figured in the wood-cut, often not more than one is required at a time, and the two

or three tubes, in place of being passed each through a separate tubulature, may be put through three holes in a cork adapted to the mouth of an ordinary bottle; and the junction be made good by soft cement or other means. A wide-mouthed jar, or bottle, will occasionally make a very good Woulfe's apparatus; and a large stone bottle often answers the same purpose even in chemical manufactories.

854. Dr. Knight, of Aberdeen, avoids much of the trouble resulting from a stiff Woulfe's apparatus, by supporting the different bottles each on sand, placed in a bowl or cup of common stone ware. That quantity of motion is then allowed which is sufficient to compensate for the casual alteration of the position of the parts; the tubes are saved from injury, and the whole works well and pleasantly; but in every case it is well to place all the bottles used upon one common base, as a board, that all may be moved together.

855. An apparatus invented by the late Dr. Nooth, and distinguished by his name, is occasionally used for the purpose of making a solution of carbonic acid. It is rather complicated, is of no general use in the laboratory, and does not require particular description; but it may be prudent to caution those who possess it, against generating *gas afresh* in the lower vessel without first ascertaining that the valve between that and the second is in right order. This is easily done by lifting the upper vessel from the lower, raising it over the head, and applying the mouth to the lower aperture of the valve tube; if the muscles of the cheeks have not power to raise this valve and blow air through it, the apparatus should not be used. The valve is always out of order when it cannot thus be raised; and from inattention to this circumstance, apparatus of the kind has, in several cases, been blown to pieces.

856. Solutions of muriatic acid, ammonia, and sulphurous acid, are generally retained upon the shelves. Solution of chlorine is often wanted, but is not usually preserved. It is readily formed by opening a bottle of chlorine (824) in an inverted position under water, allowing a little of the fluid to enter, replacing the stopper, and then agitating the contents of the vessel; in a second or two it is again to be

opened under water, when more of the fluid will enter ; it is then to be re-stopped and re-agitated, fresh water admitted, and the process thus continued until the bottle is half full. By further agitation nearly all the gas may be taken up by this quantity of water, but air should be admitted now and then to supply the place of the gas dissolved. In opening the bottle, either under water or in the air, the stopper is not to be removed farther than just sufficient to allow the ingress of the air or water, otherwise loss of the solution or of the gas is occasioned.

857. Before leaving the description of those operations which relate directly to the transference and removal of gases, it will be proper to observe that, although in making mixtures of gases they will become uniform without agitation if sufficient time be allowed, the period required will be very long, extending even to hours, in narrow vessels. If hydrogen be thrown up into a wide jar half full of oxygen, so as to fill it, and no further agitation be given, the mixture, after a lapse of several minutes, will be of different composition above and below. Hence the propriety in all cases of mixture, of agitating the gases well together. This precaution is more particularly necessary in those eudiometrical or analytical processes, which require the mixture of gases in tubes or narrow vessels. Gases are often conveniently mixed by transferring them from one jar to another through the water (757).

§ 6. *Air-pumps, syringes, and the operations performed with them.*

858. Air-pumps and syringes are instruments of great service and constant use in the laboratory, but are in their construction and reparation so necessarily the work of the instrument-maker, as to render needless here every thing relative to these points. The air-pump is required not merely in the exhaustion of receivers for experiments with atmospheres of less pressure than those ordinarily occurring, but also for the removal of air from retorts, flasks, globes, &c., that other gaseous bodies may be introduced. A good syringe will answer the same purpose to a very considerable

extent, when the air-pump is absent. It has the great advantage of combining the power of condensing air (822) with that of exhausting it, at a very little additional expense. All the screws by which the attachment of other apparatus to the pump or syringe is to be effected, should be cut with the same thread as that adopted for the stop-cocks (740, 804, 810, 827), that the screws thus used may fit each other without difficulty.

859. The student has to observe that the pistons of these instruments are well oiled, move easily and tightly, and that all the fixed joints are so perfect as to prevent leakage of air at any of the screws or junctions. The tightness of the pump is easily ascertained by screwing a stop-cock into the air aperture upon the plate, closing it, and then working the pump until the gauge indicates considerable exhaustion. When the pistons are in order, the experimenter feels, as he moves the handle, that he withdraws air each time a piston rises, and he can also perceive without difficulty that less and less is removed at each successive stroke. The diminution should proceed until none can be withdrawn by further operations; and this useless condition of the piston when at work, which is judged of by the hand (862), should coincide with the stationary and highest state of the gauge, indicative of the exhaustion within. If after some time the gauge continues to indicate the same exhaustion, it is a proof that no air can pass into a receiver fixed tightly upon the plate and similarly exhausted; and if upon working the pistons, the same absence of air is indicated beneath them as when the exhaustion was first effected, it is a proof that no air passes by them into the lower part of the pump cylinders.

860. The plate of an air-pump should be perfectly flat, and ground so smooth that a little pomatum may render a receiver with ground edges quite tight when placed upon it. It should be secured from injury by a tin cover put over it at all times when not required for experiment; for very slight blows with hard substances produce serious harm by the depressions they occasion.

861. The tightness of a syringe piston, when its other

parts are accurately fitted, may be judged of by drawing the piston as far back as possible, then closing either the exhausting or condensing aperture by a stop-cock, carrying the piston forward to the end of the cylinder, if that may be done, and retaining it there a minute or two. This motion condenses the air before the piston, and rarefies that behind it; and if the piston be not quite tight, the air will pass it, whilst it is forcibly held forward, and consequently when the hand is removed, the piston will not return, as it ought, to the top of the cylinder, or to the place from whence it was displaced. If there be leaks at the joints of the syringe, then the effect above described may be produced, although the piston be tight. In either case, the imperfection of the instrument is ascertained, and it should be sent to a workman to be repaired.

862. A syringe has not the advantage of an attached gauge like that of the pump, hence exhaustions made by it are necessarily judged of by the feel of the piston when in motion. As soon as the quantity of air removed at each stroke has diminished to nothing, the exhaustion is as complete as possible. This indication is the same as that already described with the air-pump (859), but may be more distinctly explained in consequence of one piston only being in action. It depends, generally, upon the effort made by the air to lift and pass through the valve in the piston, as the latter presses upon it. On first working the syringe, this happens immediately the piston is advanced; but as the air is more and more rarefied by exhaustion, the piston has to descend further and further, before the portion in the cylinder beneath is sufficiently compressed to lift and pass the valve. It is the particular effect of lifting the valve which, becoming sensible to the hand in ordinary air-pumps and syringes, supplies the indication in question; this is easily felt and observed, but difficult clearly to describe.

863. When the instrument is absolutely bad, and cannot be replaced or repaired, the student must compensate for the imperfections as far as he can, by interposing a stop-cock between it and the retort, flask, or other vessel (which indeed in most experiments of this kind is necessary for

other reasons), and close the communication as soon as, by rapidly working the instrument, he has effected the best exhaustion he can attain.

864. Air-pumps and syringes should be preserved from injury, likely to arise from mechanical violence or chemical action. They are best secured, not in the laboratory, but in the place appropriated to the balance (29), and other apparatus, liable to injury from acid fumes. And if in cases of emergency any gas has been passed through them, which exerts the slightest action on the metal, leather, silk, or oil, the instrument should be quickly worked in the air as soon as it can be liberated from the experiment, that the injury may, if possible, be prevented, by the instant removal of all the gas; or it should be immediately dismantled and cleaned.

865. The oiled silk valve generally applied in these instruments is exceedingly simple in construction, but liable to go out of repair quickly, especially if certain gases or vapours have passed it; on the other hand it is repaired with great facility, and its description may, therefore, be useful. It consists of an aperture of small diameter, made in a part of the metal of the piston, or of the extremity of the barrel, the aperture terminating on a flat surface; a strip of oiled silk is put over this surface and the aperture, and its ends being passed down the sides of the metal, a turn or two of thread is taken round them which confines the strip to its proper place. As the air or gas passes through the hole against the silk it easily escapes under its edges, but as the air tends to proceed in the opposite direction, it presses the silk slip against the aperture, and stops all passage. When the valve is out of order from the derangement of the silk, nothing is more easy than to remove the latter and tie another slip in its place.

866. The pressure upon the exterior of vessels exhausted of air is about 15lbs. upon every square inch of their surface, and with large vessels it accumulates to an enormous extent. For this reason the form of such as are intended to sustain this pressure, must be particularly attended to, especially when, as in usual laboratory operations, they are